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# THE MYCORRHIZAL HABIT IN RELATION TO FORESTRY

## II. ORGANIC COMPOSTS AND THE GROWTH OF YOUNG TREES

BY M. C. RAYNER

*Synopsis*

I. INTRODUCTORY.

II. EXPERIMENTS WITH ORGANIC COMPOSTS: RESULTS AND QUANTITATIVE DATA.
- (*a*) Field Plots.
- (*b*) Pot Experiments.

III. DISCUSSION OF RESULTS IN RELATION TO:
- (*a*) Recent biological theories of soil ecology.
- (*b*) The mycorrhizal habit in trees.

IV. SUMMARY.

### I. INTRODUCTION.

IN a paper published in this journal in 1934 (7), reference was made to the remarkable effects produced on the growth of seedling conifers by the addition of certain organic composts to soils in which, untreated, the young trees suffer high mortality and marked inhibition of growth.

In the case of one such soil from poor heathland in south Dorset, the possible causes of infertility in reference to tree growth were discussed in a previous publication (6). At an early stage of the work the view had been reached that the poverty in nutrients characteristic of these soils was, in this case, reinforced by factors directly inimical to root growth. The exact nature of such toxic factors is still uncertain, but a clue to their identity is provided by a recent communication pointing to the presence of chemical regulators of plant growth in certain organic soils (5). The purpose of the present paper is to give a more complete record of the compost experiments referred to, provide the quantitative data not included in the preliminary account, and discuss the significance of the effects observed.

The composts in question may be classed in three groups according to the materials used in their manufacture. In the first group are those made from straw (C 1, C 7, C 8), in the second, those derived from sawdust (C 2, C 4, C 6), and in the third group those of other origins, of which only one (C 5), made from brewery hop waste, need be considered at this stage; others, falling into this group, are under observation. In all cases composting is carried out by the addition of one part of nitrogen to one hundred parts of the material to be composted, calculated from the latter in air-dry condition. Three different sources of nitrogen were used in this process, namely, dried blood, ammonium sulphate, and ammonium phosphate. In the first group, the material used as a basis was clean wheat or oat straw chaff composted with equivalent amounts

of dried blood (C 1), ammonium sulphate (C 7), or ammonium phosphate (C 8) respectively. In the second group, preliminary experiments with hardwood and softwood sawdusts gave unexpected results, pointing conclusively to softwood sawdust as the more satisfactory basis. Alternatively, freshly fallen birch leaves and straw chaff were added to expedite the composting process, these mixtures likewise giving surprising results, inasmuch as a compost derived from 75 per cent. softwood sawdust mixed with 25 per cent. straw chaff (C 6) gave markedly better and more consistent results than the corresponding mixture with hardwood sawdust; better also than 50 per cent. hardwood sawdust or softwood sawdust mixed with 50 per cent. fresh birch leaves (C 2 or C 2*), or 50 per cent. straw chaff (C 4 or C 4*). All sawdust composts were composted with dried blood added in the proportion of 1 part to 100 parts of air-dry material. Some have given results that challenge attention both in the field and in pot culture, although they do not compare in magnitude with those obtained from certain of the other composts (Figs. 5, 6, 7). In view of the low cost of the raw materials and the ease with which they can be obtained, these composts in the second group are of practical importance; they are regarded as still in the experimental stage, and it is believed that certain modifications in the methods of composting may render them more effective. In the third group, one compost (C 5), prepared by the addition of 1% nitrogen in the form of dried blood to fresh brewery hop waste, has been fully tested and has given outstanding results (Figs. 2–7). All conclusions were based on consistently regular results from several years experiments, both in field plots and pot cultures.

The choice of raw materials for the composts was influenced in the first instance by observations on the growth of hymenomycete mycelium; necessarily also by initial cost of materials, the ease with which they could be procured, and the desire to produce an end product of standard composition. Much care has been given to the details of the composting process. The heaps are made up under cover with sufficient floor space for convenient turning. With air-dry materials, such as straw and sawdust, water is added carefully in sufficient amount to give a moist but not wet substrate, ensuring sufficient moisture for microbial activity and proper consolidation of the heap. The powdered nitrogenous material is added in such manner as to ensure even distribution, and the heaps then consolidated. Thermometers are inserted for the observation of internal temperatures. Great care is necessary during the early stages of composting to avoid excessive heating and local drying out. Temperatures are controlled and regulated by turning the heaps and adding water as necessary. In all cases, the temperature charts show a rapid rise to a maximum within 7 to 10 days, followed by a slow decline to a level at which the temperature remains constant for some weeks.

The maxima reached or permitted vary from 78° F. in some of the straw composts to 65° F. or less in those composed of sawdust. The rate of composting varies with the nature of the materials and the management of the heaps. Some are ready for use six weeks to two months from the date of

making up, others require a longer period. All those tested have been found equally effective a year later. When ready for use, some of these composts are almost indistinguishable in physical characters, odour, &c., from old woodland mull.

It must be noted that they were not designed to act as manures or direct stimulants to growth. Their use was directed to relieve conditions believed to be inhibitory to the root growth of seedling pines in a heath soil of poor organic type. It was not held that the prevailing poverty in nutrients was an effective limiting factor to growth of the young trees; the view had been reached that, on this soil, as probably on those of similar type elsewhere, *qualitative* changes in the organic constituents following directly upon modification of the biological activities were responsible for the observed inhibition of growth and mycorrhizal activities.

Apart from the production, locally, of actively toxic substances, it was thought that such changes might include an abnormally high ratio of cellulosic to lignin constituents. Whether this crude working hypothesis is susceptible of direct proof is still in doubt and does not affect the general point of view outlined above. It receives support from the observed fact that additions of pure cellulose to a similar type of humus soil favourable to the growth of young pines brings about markedly deleterious effects on root growth. Further discussion of these and related observations must await the accumulation of experimental data bearing directly on the problem.

The unfavourable conditions presented by the Dorset soil were indicated by high mortality and more or less complete inhibition of growth, with irregular and inconstant emergence from check in seedlings and transplants of various species of pine. Root growth was markedly defective with almost complete suppression of short roots and consequently of mycorrhizas, although there was evidence of the presence on the area of at least one known mycorrhiza-former of Scots pine, viz. *Boletus bovinus*. It is not without significance that sporophores of this fungus are frequent in the neighbourhood of young trees that have emerged from check spontaneously and are growing freely.

The general hypothesis of qualitative changes in the humus leading to the production of a substrate unfavourable alike to growth of the mycorrhiza-forming fungi and to root activities was founded on earlier observations and is discussed more fully in a later section of this paper. In the case of the Dorset soil, the effect of compost treatments in relieving the deleterious conditions has been tested both in field plots and in pot cultures with transported soil.

A preliminary account of these experiments has been published (7). The quantitative results yielded by them at the end of three years' growth will now be considered. Their uniformity and magnitude are alike remarkable.

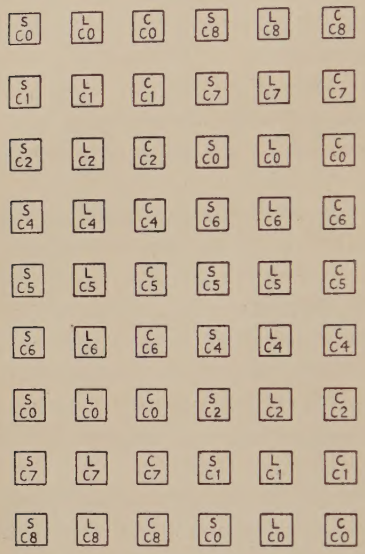
## II. EXPERIMENTS WITH ORGANIC COMPOSTS.

### (*a*) *Field Plots.*

The general layout of the field plots is shown on the plan now reproduced (Fig. 1). Control plots (C o) are quadruplicated, and those treated with seven

different composts (C 1, C 2, C 4, C 5, C 6, C 7, C 8) are each duplicated. Every treated plot received a dressing of 10 lb. of compost (moisture content about 75 per cent.) per square yard, spread and lightly forked in before sowing.

There were two experimental areas on ploughed land, one under the worst conditions of exposure, &c., the other under slightly better conditions of soil and exposure. With certain minor exceptions, the qualitative results were identical from the two areas, as was also the degree of difference between control and treated plants. On the better area, as might be expected, there was a slight 'scaling up' in the size of plants both from control and treated plots, leaving the ratio unaffected.


S C0 L C0 C C0 S C8 L C8 C C8
S C1 L C1 C C1 S C7 L C7 C C7
S C2 L C2 C C2 S C0 L C0 C C0
S C4 L C4 C C4 S C6 L C6 C C6
S C5 L C5 C C5 S C5 L C5 C C5
S C6 L C6 C C6 S C4 L C4 C C4
S C0 L C0 C C0 S C2 L C2 C C2
S C7 L C7 C C7 S C1 L C1 C C1
S C8 L C8 C C8 S C0 L C0 C C0

Text Fig. 1. Layout of part of experimental plot.

Three species of pine—Scots pine, Corsican pine, and *Pinus contorta* var. *murrayana* Engelm.—were under observation. Seed was sown in shallow drills as in ordinary nursery practice. The plots were sown in April 1933, and the seedlings suffered exceptionally unfavourable conditions during the dry, hot summers of 1933 and 1934 that followed. In spite of this, growth of the seedlings of the three species of pine on plots treated with certain composts, notably C 5 and C 1, was remarkably vigorous from the first, and on all treated plots was markedly better than that of controls. The growth reactions were uniform on like plots, and the immensely increased growth of the treated seedlings continued without diminution throughout the second and third growing seasons. The large populations carried by these plots and their uniformity of growth are evident from the photographs and diagrams now reproduced (Plates I, II, III, IV, figs. 1–12).

Representative 2-year-old seedlings from control plots and from those treated with composts C 1 and C 5 were figured in the first paper of this series (7). Control plants made little growth after the first year; the majority of all species were very small, stationary as to growth, and of poor colour (Plates I, II, III, figs. 1, 4, 7). On the more exposed area, those of Corsican pine and of *P. contorta* in particular were practically moribund when the final records were made; on the better area, a few plants on some of the control plots of Scots pine were green and growing slowly.

In the late summer of 1935, the results of these experiments were recorded: (*a*) by a complete photographic record of all plots; (*b*) by comparative height measurements of individual plants. For the latter, two methods were employed. The average height of seedlings from all plots was obtained by

making direct measurements of the heights from ground level to top of the terminal bud on twelve seedlings from each plot, using an arbitrary grid to give the position of the selected plants. As a check on the average heights thus obtained, similar measurements were made on whole populations of control plots and of those of certain treatments. These results are recorded graphically in the six figures now reproduced. Three of these record the average heights of plants from controls and from seven compost treatments based on grid measurements from three plots of each treatment and twelve plants per plot. On one side of the graph the records are arranged in compost groups; on the other, in descending order of magnitude. The remaining three figures are height-frequency graphs for whole populations of control plots (CO), and those treated with compost C 5 respectively.

Co Control, no compost.
C 1 Compost prepared from straw+dried blood.
C 2 (or C 2*) „ „ „ 50 per cent. hardwood (or softwood) sawdust +50 per cent. birch leaves+dried blood.
C 4 (or C 4*) „ „ „ „ „ „ „ straw+dried blood.
C 5 „ „ „ brewery hop waste+dried blood.
C 6 „ „ „ 75 per cent. sawdust+25 per cent. straw+dried blood.
C 7 „ „ „ straw+ammonium sulphate.
C 8 „ „ „ „ +ammonium phosphate.

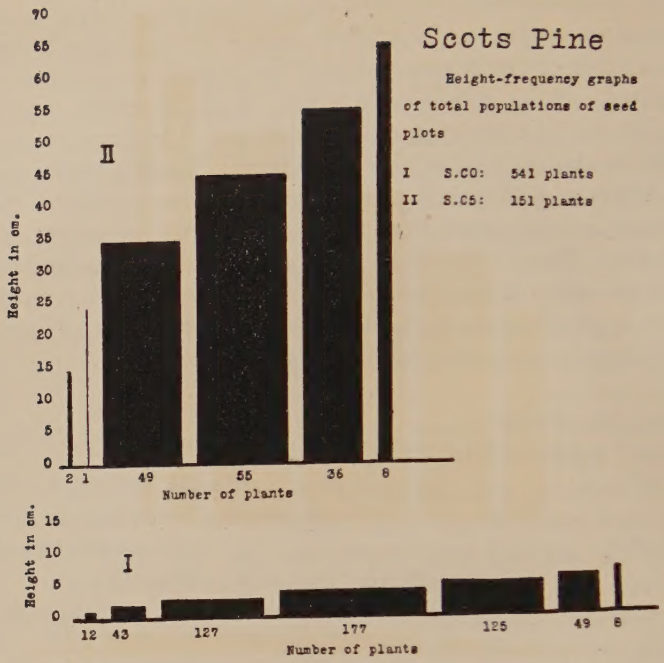
In each instance the nitrogen added was one hundredth the air-dry weight of the composting material. 10 lb. of compost added per square yard.

*Cost of composts.* C 1: 15 cwt. of straw gives approximately 1 ton 15 cwt. of compost. Cost of labour in London for composting is 7*s.* to 7*s.* 6*d.* per ton.

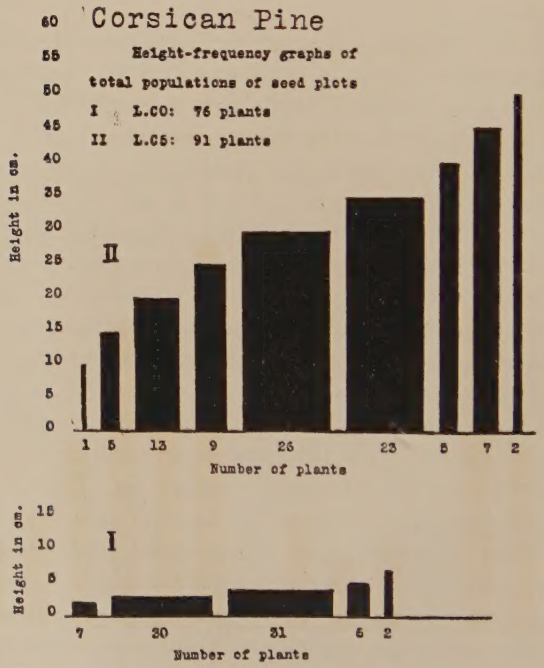
C 5: 8 tons of spent hops gives approximately 5 tons of compost. Cost of labour in London for composting is 2*s.* 6*d.* to 2*s.* 9*d.* per ton.

It will be noted that the average heights calculated on a basis of grid measurements on three plots (36 plants) in all three species of pine (Figs. 5, 6, 7) are slightly lower than the greatest frequency heights recorded in complete measurements of corresponding plots (Figs. 2, 3, 4). The comparative heights given by compost treatments yielding major results are in agreement for all species; i.e. in descending order of magnitude, C 5, C 8, C 1, C 7, C 6.

C 5 and C 8 both contain significant amounts of phosphate, in the one case as a primary constituent, in the other as an addition in the ammonium phosphate used as a source of nitrogen in composting. The results yielded by these two composts are interpreted as due in each case to 'compost effect' plus 'manurial effect' following upon the increased supply of phosphate (see Appendix). The growth results were generally consistent throughout three growing seasons, except in respect to a slightly improved response to C 8 as compared with C 1 during the second and third years. The remarkably free and vigorous root development shown by treated plants in the second year




TEXT FIG. 2.

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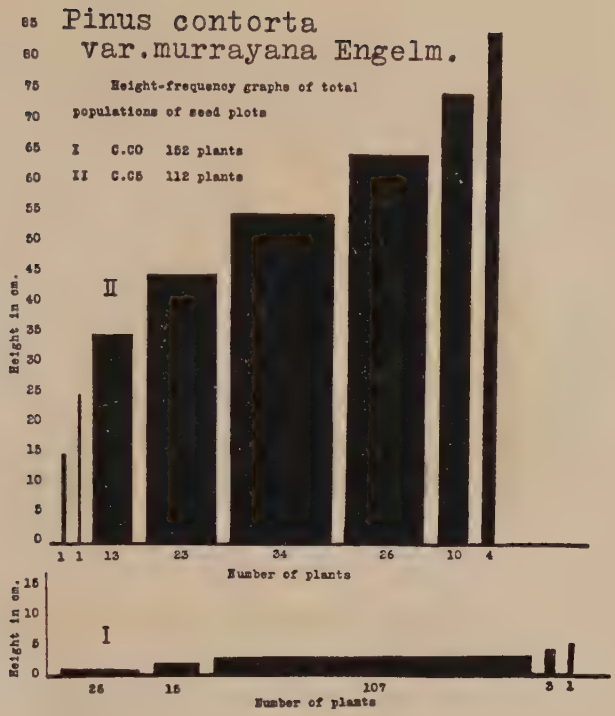
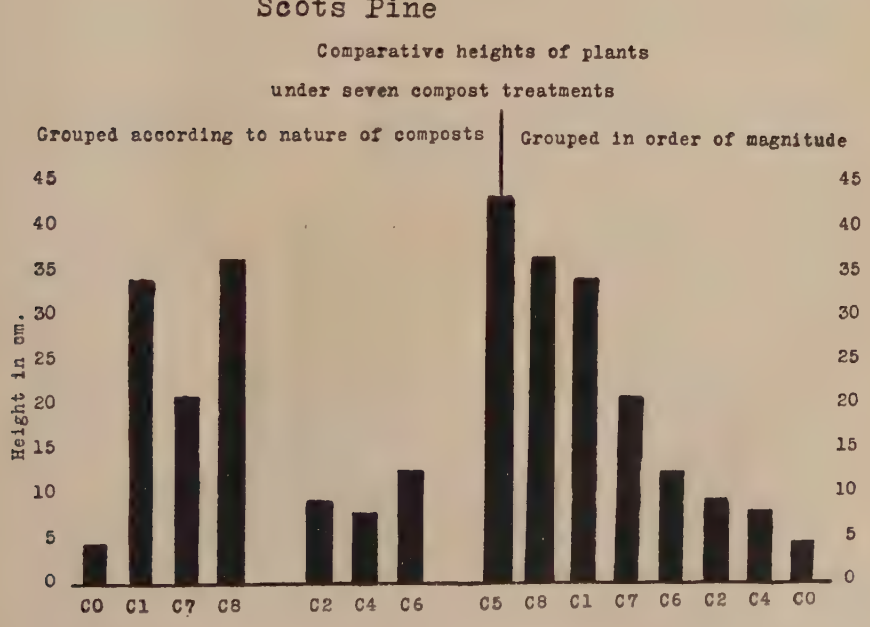
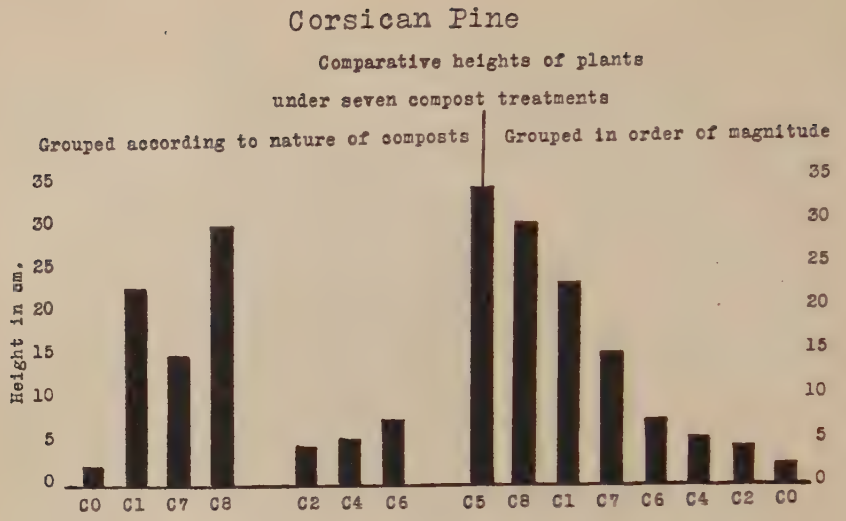


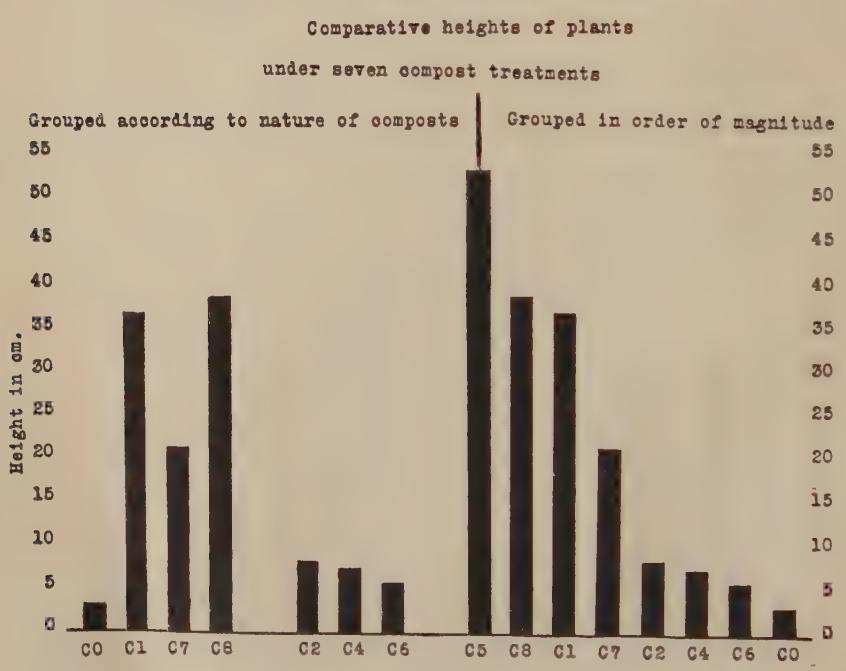

TEXT FIG. 4.


Scots Pine
Comparative heights of plants
under seven compost treatments
Grouped according to nature of composts
Grouped in order of magnitude
Height in cm.
C0 C1 C7 C8 C2 C4 C6 C5 C8 C1 C7 C6 C2 C4 C0

TEXT FIG. 5.




Text Fig. 6.




Text Fig. 7.

was fully maintained during the third season of growth, the extensive root systems and crowding of the plants on the plots making comparative measurements by dry-weight estimation impracticable.

As compared with those of controls, the root systems of treated plants are distinguished by abundance of short roots and profuse development of mycorrhizas (Plate V, figs. 1–6). A fungus, identical in pure culture with two strains of *Boletus bovinus* isolated from sporophores from Swedish woods and from elsewhere in the Dorset area respectively, has been isolated from mycorrhizas of plants on treated plots. It is believed, therefore, that mycelium of this fungus is present throughout the soil of the experimental area, but is inhibited as a mycorrhiza-former by soil factors not fully determined. The addition of certain composts relieves this condition, permitting normal activity of the mycelium and formation of stable and balanced mycorrhizal associations. This interpretation is reinforced by observations on the structural features of the mycorrhizas of plants with certain composts—notably those of the second group, C 6, C 4, and C 2.

It is not proposed at this stage to attempt a complete analysis of these observations on the mycorrhizas of the experimental plants. It may be concluded, however, that the use of organic composts as now indicated provides a method of some delicacy for testing the reactions of mycorrhizal structure to changes in the organic constituents of the soil environment. For example, composts C 1 and C 7 differ only in respect to the sources of nitrogen used for the composting process. The analyses show no significant differences in respect to available nutrients. On the other hand, they differ remarkably in their effects upon the growth of pine seedlings and also in respect to the mycorrhizal responses shown by treated plants (see Appendix).

The conclusion that these effects are directly related to differences of composition associated with a distinct series of biological changes in each case is irresistible. The different courses taken by the biological activities responsible for the decomposition changes during composting is shown by variations in the temperature charts and in the fungus flora carried by the heaps at various stages.

Field experiments other than those just recorded, in which composts alone were employed, also were carried out. In one series the same quantities of composts were used, together with inoculation of each plot with small amounts of humus containing active mycorrhizas of the species; in another, inoculation from pure cultures of an appropriate mycorrhiza-former replaced that with humus. The early results of these experiments have been placed on record. A fuller account of them may be postponed with advantage until the comparative effects produced by compost treatment alone, inoculation alone, and compost treatment together with inoculation have been tested by a longer period of growth.

(*b*) *Pot Experiments.*

The field experiments were repeated in a complete series of pot cultures grown in the garden of the Department of Botany, Bedford College, University of London.

A general account of these with photographs of the growing plants have been published (7). This is now supplemented by dry-weight records of all cultures at the end of the third growing season (Tables I, II, III). Neither conditions of pot culture nor the London climate are favourable to the cultivation of conifers. Under the relatively sheltered conditions provided by a special house, the plants were healthy and vigorous, but growth was inevitably restricted in some degree so that even the largest plants were considerably smaller than those from the corresponding field plots. A certain amount of leaching is unavoidable in long period pot cultures, and this might be expected to affect growth by progressively decreasing the potential supply of nutrients and possibly also by removing substances initially present deleterious to growth. The latter possibility, together with the improved aeration and shelter attend-

TABLE I. *Table showing comparative dry weights of plants from pot cultures of Scots pine grown in Wareham soil alone, and with addition of seven different composts.*

*Scots Pine*

Sown 11 May 1933. Lifted 28 June 1935.

| *Treatment.* | *Number of plants.* | *Weight in grammes: actual.* | *Weight in grammes: per 100 plants.* |
|---|---|---|---|
| S.C 0 | 84 | 12·47 | 14·8 |
| S.C 2 | 69 | 33·32 | 48·3 |
| S.C 4 | 66 | 39·10 | 59·2 |
| S.C 6 | 65 | 38·80 | 59·7 |
| S.C 1 | 63 | 41·15 | 65·3 |
| S.C 7 | 71 | 49·40 | 69·6 |
| S.C 8 | 42 | 35·60 | 84·7 |
| S.C 5 | 51 | 59·60 | 116·8 |

TABLE II. *Table showing comparative dry-weight values of plants from pot cultures of Corsican pine grown in Wareham soil alone, and with addition of seven different composts.*

*Corsican Pine*

Sown 11 May 1933. Lifted 28 June 1935.

| *Treatment.* | *Number of plants.* | *Weight in grammes: actual.* | *Weight in grammes: per 100 plants.* |
|---|---|---|---|
| L.C 0 | 35 | 17·6 | 50·3 |
| L.C 4 | 45 | 39·7 | 88·2 |
| L.C 6 | 46 | 52·8 | 114·8 |
| L.C 2 | 40 | 47·7 | 119·2 |
| L.C 1 | 51 | 63·8 | 125·1 |
| L.C 7 | 32 | 47·5 | 148·4 |
| L.C 8 | 13 | 24·5 | 188·2 |
| L.C 5 | 29 | 56·0 | 193·0 |

TABLE III. *Table showing comparative dry-weight values of plants from pot cultures of Lodgepole pine* (P. contorta *var.* murrayana *Engelm.*) *grown in Wareham soil alone, and with seven different composts.*

*P. contorta* var. *murrayana* Engelm.

Sown 11 May 1933. Lifted 28 Jan. 1935.

| *Treatment.* | *Number of plants.* | *Weight in grammes: actual.* | *Weight in grammes: per 100 plants.* |
|---|---|---|---|
| C.C 0 | 107 | 9·50 | 8·9 |
| C.C 4 | 55 | 15·67 | 28·5 |
| C.C 6 | 56 | 21·15 | 37·8 |
| C.C 2 | 57 | 25·90 | 45·4 |
| C.C 7 | 46 | 32·02 | 69·6 |
| C.C 1 | 50 | 39·48 | 78·9 |
| C.C 8 | 43 | 37·25 | 86·6 |
| C.C 5 | 47 | 43·70 | 92·9 |

ing pot culture would favour growth of the control plants, while removal of nutrients and restriction of rooting area would press most heavily on those cultures with larger and more vigorous plants. Taking into account such disturbing factors, there is a close agreement between the results of the pot experiments based on dry-weight estimations and those of field plots based on height measurements. Allowing for the smaller size of the pot plants there was close comparative agreement likewise in general vigour, colour, and length of needles. For all three species of pine the order of magnitude of compost effects as deduced from dry weights is in agreement with that from field plots based on height measurements with certain minor exceptions. One of these, the improved position of C 7 as compared with C 1 in the pot cultures, may be due to leaching, since there was some indication in corresponding field plots of a disturbing factor not associated with the closely similar composts, C 1 and C 8.

In the more favourable treatments especially, the pots were crowded with roots at the end of the second year, and the dry weights of the plants when finally recorded were undoubtedly considerably smaller than would have been the case had it been practicable to use larger pots. In the case of Corsican pine, this effect was aggravated in certain cases by irregularities in the numbers of plants per pot following upon low germination capacity (see Table II). In all three species of pine the rooting reactions and mycorrhizal responses, as between controls and treated plants, correspond generally with those observed in field plots of the same treatments. Consideration of minor inconsistencies in the responses shown by pot plants to the C 6, C 4, C 2 group of composts may be postponed until further experimental data for these treatments are available.

In the preliminary account of these experiments mention was made of the different reactions to the same compost shown by individual species of pine on

different soils, and also of the differential growth responses by various coniferous species on the same soil. The three species of pine used for the experiments just described show this differential response in some degree. It is exhibited even more strongly by European larch in a series of pot cultures receiving similar treatment, and grown under the same conditions as those with pines. As might be anticipated, control sowings of larch on this poor heath soil gave results almost negligible as regards size and quality of the plants. The small seedlings about 1 cm. high suffered severely during the first year, and the survivors showed no improvement later. Those treated with the standard addition of C 5 provided a striking contrast, the vigorous growth becoming more marked during the second season. The young trees continued to grow freely during the third season, in spite of leaching due to continuous watering and of severe competition owing to crowding of the plants. They were repotted in October of the third year and are still under observation. None of the other composts evoked response during the first year; in the second season C 1 plants made unexpectedly active growth of both roots and shoots, remaining treatments being inert or inducing only slight and irregular responses in a few seedlings. The photographs now reproduced illustrate these effects and are in each case representative of the plants included in the twelve pots of each treatment (Plate VI, figs. 1, 2, 3).

These experiments with larch have been extended to field sowings and pot experiments in other types of soil, and also to inoculation treatments with *Boletus elegans*, a constant mycorrhizal associate of larch.

Consideration of these aspects leads naturally to inquiry respecting the nature of the growth effects observed. Evidence has been offered that these—except in certain cases noted—differ essentially from those following the use of manures supplying available nitrogen, potash, and phosphate. Support for this is found in the differential responses to different composts observed in soils of similar type and given by individual conifer species. Reference may be made also to the chemical analysis of several of the composts in the appendix to this paper. Evidence of a more direct kind has been obtained from pot experiments with a typical garden 'potting soil',[1] with additions of standard amounts of certain composts. One such experiment with tomato has been recorded and illustrated (7). The use of such cultures has been extended to Scots pine and a number of plant species other than conifers, the amounts of composts added being always the same as in the original pot experiments. The results of these preliminary experiments expressed in dry-weight values are now placed on record (Tables IV, V). The selection of species was influenced by their proved suitability for pot culture as well as by the desire to have under observation simultaneously representatives of two classes of plants; those free from mycorrhizal infection, and those known to form associations with mycelium of the 'phycomycete type' representatives of which might with reason

[1] The potting soil used was a standard mixture of the following constitution: 3 parts virgin loam (Kent yellow), 2 parts leaf soil (3-year-old decayed leaves of garden origin, mostly plane and elm), and 1 part silver sand (Bedford silver-sand pits, Bedfordshire).

TABLE IV. *Table showing comparative dry-weight values of tomato, wallflower,* Nicotiana spp., Solanum *and Scots pine grown in potting soil with and without addition of composts.*

| *Plant.* | *Compost.* | *Number of plants.* | *Duration in days.* | *Dry weight in grammes.* | | *Remarks.* |
|---|---|---|---|---|---|---|
| | | | | *control.* | *treated.* | |
| *Tomato (Sunrise) | C 7 | 6 | 93 | 15·7 | 13·8 | Aug.–Nov. 1934. Flowering. No difference in stature, root system, size or colour of leaves, or flowering in controls and treated plants. No mycorrhizal infection. |
| *Tomato (Sunrise) | C 1 | 6 | 120 | 41·6 | 38·6 | June–Oct. 1935. Fruiting. No difference in stature, root system, size or colour of leaves, or flowering in controls and treated plants. No mycorrhizal infection. |
| †Wallflower (Bush) | C 7 | 6 | 217 | 19·8 | 16·5 | July 1934–March 1935. Fully grown but not yet flowering. No difference in stature, root system, size or colour of leaves in controls and treated plants. No mycorrhizal infection. |
| †*Solanum dulcamara* | C 1 | 6 | 165 | 28·9 | 32·5 | June–Nov. 1935. Not yet in flower when soil exhausted. No observable difference in stature, root system, size or colour of leaves in controls and treated plants. Mycorrhizal infection of 'Phycomycete type' rather feebly developed both in controls and treated plants. |
| **Nicotiana affinis* (Crimson Bedder) | C 1 | 6 | 165 | 23·7 | 40·0 | June–Nov. 1935. Flowering freely. No observable difference in stature, root system, size or colour of leaves, or flowering in controls and treated plants. Profuse mycorrhizal infection of characteristic type both in controls and treated plants. |
| †*Nicotiana tabacum* | C 1 | 6 | 164 | 30·0 | 40·9 | June–Nov. 1935. Not flowering. Treated plants larger than controls in stature and size of leaves. Profuse mycorrhizal infection of characteristic type both in controls and treated plants. |

* Messrs. Carter. † Messrs. Thompson and Morgan.

TABLE IV (*cont.*).

| *Plant.* | *Compost.* | *Number of plants.* | *Duration in days.* | *Dry weight in grammes.* | | *Remarks.* |
|---|---|---|---|---|---|---|
| | | | | *control.* | *treated.* | |
| Scots pine (*P. silvestris L.*) | C 1 | 100 | 385 | 24·9 | 27·3 | Apr. 1935–Apr. 1936. No difference in stature, root system, size or colour of needles in controls and treated plants. Normal mycorrhizas formed in both series. |

TABLE V. *Table showing comparative dry-weight values of tomato and wallflower grown in Wareham soil with and without addition of composts.*

| *Plant.* | *Compost.* | *Number of plants.* | *Duration in days.* | *Dry weight in grammes.* | | *Remarks.* |
|---|---|---|---|---|---|---|
| | | | | *control.* | *treated.* | |
| *Tomato (Sunrise) | C 1 | 6 | 120 | 0·15 | 17·5 | June–Oct. 1935. Controls—remains of very small seedlings only. Colour of foliage very dark, and to less extent in treated also. No mycorrhizal infection. |
| ,, | C 5 | 6 | 120 | 0·15 | 36·3 | |
| †Wallflower (Bush) | C 7 | 6 | 217 | 3·15 | 2·85 | July 1934–March 1935. Plants very small, but foliage of normal coloration; leaves small, few roots. Effect of C 5 evident after a month's growth; that of C 6 rather later. |
| | C 6 | 6 | 217 | 3·15 | 5·55 | |
| | C 5 | 6 | 217 | 3·15 | 10·39 | |

* Messrs. Carter. † Messrs. Thompson and Morgan.

be expected in the potting soil used. Of the plants listed in Table IV, tomato and wallflower belong to the first class. So far as I am aware, there is no record of mycorrhizal association for either of these species, and careful examination of roots of the experimental plants has not revealed any trace of fungus infection. In the second class, *Solanum dulcamara*, *Nicotiana affinis*, and *N. tabacum* were selected as known mycorrhiza-formers. Under the conditions of the experiment all three species showed mycorrhizal infection of the well-known 'phycomycete type'; in *Solanum* rather feeble, in the two species of *Nicotiana* profuse and characteristic. For comparison with pines, pot experiments with tomato and wallflower were duplicated using Wareham soil instead of potting soil (Table V). Used alone, the former is almost lethal to both species, especially to tomato; in the fresh soil there is almost complete inhibition of root production and growth. In the case of tomato, addition of C 1 reduces this effect, permitting relatively normal growth, the increase in dry

weight being doubled by the substitution of C 5. The characteristic darkening of the foliage is much decreased by the addition of composts. In wallflower no effect on growth was produced by the use of C 7, whereas a corresponding dose of C 6 doubled the dry weight, and of C 5 trebled it. No data are at present available for *Nicotiana* or other mycorrhiza-forming species on this soil. Those obtained for tomato and wallflower are too scanty to have any critical value: moreover, complicating factors may arise in the case of species known to be sensitive to soil acidity; but they illustrate the general effect of these composts in counteracting the factors inimical to root activity in the Wareham soil and also the differential effects on growth produced by composts so closely similar in origin and composition as C 6 and C 7. These experiments must be repeated and extended in various directions before the results can be used as a basis for final conclusions. It is, however, regarded as probably not accidental that, in the experiments in which 'potting soil' was used, tomato and wallflower show no trace of improved growth following the addition of compost, whereas the corresponding cultures of *Solanum* and *Nicotiana* spp. have higher dry-weight values than the controls without compost. This accords with recent observations in California on *Citrus* with the same type of mycorrhizal infection (8), and favours the view that the mycorrhizal habit may affect indirectly the growth reactions of the hosts and should be taken into account in the manurial treatment of crop plants.

It will be noted that the behaviour of Scots pine in potting soil agrees with that of tomato and wallflower. There is no trace of the remarkable effect on growth produced by the addition of a corresponding amount of this same compost to Wareham soil. Seedlings in both groups formed typical mycorrhizas at the end of the summer, the source of infection being almost certainly from outside and not from the potting medium. In the remaining plants of the series it will be of interest to observe whether a differential effect, corresponding to that indicated in *Nicotiana* spp. and *Solanum*, is associated also with pine mycorrhizas following the addition of organic material. In the case of tree seedlings such difference could become apparent only after another growing season.

## III. DISCUSSION OF RESULTS.

### (*a*) *Recent Biological Theories of Soil Ecology.*

In 1932 Romell published a paper entitled 'Mull and Duff as biotic equilibria', in which he directed attention to the importance of *type* of decomposition compared with *rate* of decomposition as the significant factor in determining the kind of humus layer produced in organic soils (9).

He places on record in this paper the somewhat surprising conclusion that 'typical brown soil profiles with crumb mull' may represent just as high a humus accumulation as 'podsol profiles with a heavy duff'. Pleading for a return to the biological theory of humus decomposition, reference is made to the view of P. E. Muller, 'the father of modern soil science', who regarded

the humus layers in the forest as a biological unit and held that the different types of humus layer depended on differences in types of decomposition, in contrast with the modern view which regards duff formation, for example, as resulting essentially from 'stagnation of the decomposing process'. Romell's conclusions were unknown to the writer when the hypothesis outlined in the present paper was used as a basis for the use of organic composts as a means of bringing about qualitative changes in the humus constituents of an unfertile organic soil. As recorded in the paper just cited, and in the more recently published 'Ecological Problems of the Humus Layer in the Forest' (10), they afford welcome support on the side of soil science to this hypothesis, whose inception was due to observations and experiments along an entirely different line of work. In its general form, the hypothesis that qualitative changes depending on a 'shift' of the biological activities may lead, in certain cases, to the production of a substrate unfavourable to growth alike of the mycorrhiza-forming fungi and of tree roots, was founded on intensive study of various species of pine in Great Britain and elsewhere over a period of some years. Attention became focused on the delicacy with which differences in the root environment were reflected, not only in the intensity of mycorrhizal development, but also in the structural features of individual mycorrhizas. This sensitiveness and the structural peculiarities observed were remarkably uniform wherever sought, independently of geographical or climatic differences, or of the species of pine under observation, the evidence pointing to the humus constituents as the source of the potentially active factors.

As now interpreted, the results stated in the earlier (7) and present papers appear to dovetail with Romell's conclusions in respect to forest soils, inasmuch as the qualitative changes artificially induced by the use of composts are obviously linked with changes in biological activity and associated with profound effects both on the growth of the young trees and on their mycorrhizal behaviour. Positive evidence of this is afforded by the activity and functioning of mycorrhiza-forming fungi previously inhibited, by the emergence on the treated plots of sporophores of various hymenomycetes not previously observed, and by the appearance of earthworms. The conclusion that the remarkable effects on growth are related with changes of the kind indicated and do not depend upon the addition of significant amounts of available nutrients follows from study of the evidence available; the manner in which they are so related calls for further investigation. The general view held at present is as follows. The apparent stagnation in respect to humus decomposition in this soil and possibly in others of similar type is due to changes in the biological activities depending on local causes. In consequence there is produced a substrate unfavourable to root growth and nutrition and likewise to certain microbiological activities closely bound up with them. Under certain conditions, probably seasonal, there are indications that volatile substances directly affecting root growth may be produced. It is regarded as significant that it has been found possible to establish experimentally a direct relation between the activity of certain mycorrhiza-formers

and marked stimulation of the growth of short roots. Whether this effect depends *directly* upon the formation of definite growth-promoting substances of auximones, or *indirectly* upon increased production of nutrients, is at present unknown, but it is now suggested that the facts actually established open up more than one line of research of fundamental importance to a correct understanding of tree nutrition. Is it premature to suggest that there is a real parallelism between the changes leading to infertility in this heath soil, and those responsible for the abnormal accumulation of duff in forest soils; that in both cases effects adverse to tree nutrition may ensue, reflected not only in the degree of mycorrhizal development but in the structural peculiarities of the mycorrhizas themselves? The evidence points in this direction and suggests that the observations referred to in a later paragraph (p. 18) may find their place in a scheme sufficiently comprehensive to embrace also the conclusions set out in the present paper. To elaborate the details of such a scheme would tax heavily the resources of any single investigator; it calls for the united efforts of the expert in soil science, the botanical specialist, and the forester. The problem of what constitutes 'typical' mycorrhizal structure or range of structure for a given species and what should be regarded as 'pseudomycorrhizal', using this term in a quite general sense to cover deviation from those structural features believed to be characteristic of balanced associations in the species under different soil conditions, is of fundamental importance in this connexion and calls for further research along the lines rendered classical by Melin and others.

### (*b*) *The Mycorrhizal Habit in Trees.*

The present occasion does not call for a general discussion of the vexed problem of the significance of the mycorrhizal habit in trees, nor indeed is the time yet ripe for such discussion. On the other hand, certain aspects of the problem appear to have so intimate a relation with the results of the experiments now described that their significance merits attention. At the outset it may be admitted frankly that conclusive evidence concerning the physiological role of the mycorrhizal fungi in tree nutrition is still lacking.

Fundamental questions as to the existence and nature of the interrelation between root cells and mycelium can be answered only by the method of pure culture. As the problem now presents itself, however, it appears to the writer that the stage when this method can be employed profitably has not yet been reached. In the case of trees, the problem is evidently extremely complex: the multiple habit in respect to fungal association; the implication that 'balanced' relations may call for different associates to meet a variety of soil conditions; the overthrow of what appears to be a balanced relationship as deduced from structural changes with the appearance of features described as 'pseudomycorrhizal' or requiring fresh definition; structural peculiarities interpreted as reactions to specific soil characters; all these point to the mycotrophic habit in trees as linked up with an intricate system of other biological soil activities, knowledge of which might render it more possible

than at present to define with precision the ultimate problems of tree nutrition. It is not possible to reproduce under pure-culture conditions the dynamic fluctuating system with which the habit is associated in nature. For this reason it is not, in my view, necessary to accept as conclusive such negative evidence as that presented by McArdle (3) and others. On the other hand, it is impossible to study the habit intensively in the field and in the laboratory without suspecting that a relationship so finely adjusted to environmental charges and so readily correlated with the health and vigour of the hosts, must play a fundamental part in their nutrition and growth.

Evidence of a direct causal relation between mycorrhizal development and healthy growth in young pines has been offered (7). Of importance, it is believed, are the conclusions put forward in the paper that the introduction of active mycorrhizal material into an unfavourable soil 'leads directly to the production of growth-promoting substances in the substrate', and also the observation now recorded that the addition of certain organic composts to a soil in which mycorrhizal activity is inhibited, although evidence exists of the presence of appropriate fungi, leads to reversal of the inhibiting mechanism accompanied by vigorous growth of the trees and profuse development of mycorrhizas.

It is believed that these phenomena are interrelated and justify the following conclusions as a basis for further observations and experiments.

1. In woodland soils of the raw humus type a stage of humus decomposition marked by activity of the mycorrhiza-formers—possibly by that of hymenomycete mycelium in general—is related directly with conditions favourable to tree nutrition, the formation of mycorrhizas typical for the species indicating a definite phase in the process. In the light of the rather fragmentary evidence available, in particular of the observations recorded in the present paper, it is suggested that a linked series of humus decompositions is characterized at a relatively advanced stage by activation of the mycelium of the mycorrhiza-formers of trees, possibly also by that of related basidiomyces. With this is bound up the evolution of an environment stimulating the production of short roots and promoting a physiological state both in young rootlets and in the mycelium favourable to mycorrhiza formation. Rapid accumulation of duff indicates the onset of changes unfavourable to these activities and thus leads inevitably to interference with the development of normal mycorrhizas and to disturbances of nutrition.

It is believed that such disturbance in tree nutrition can be influenced by promoting qualitative changes in the litter materials by addition of prunings, slashings, or otherwise; furthermore, that direct evidence for this view is already on record in forestry literature, although co-ordinated observations on the botanical side bearing on mycorrhiza development are not yet available (2, 4). Whether the earlier changes take the form of shifts in the incidence of bacterial as compared with fungal activity as suggested by Romell is uncertain (10). Nor is there at present direct evidence of how such hypothetical changes can be related directly with the later stage of mycorrhizal activity.

2. The hypothesis just outlined can be extended to non-woodland soils in which difficulty is experienced in establishing young trees; e.g. those associated with certain Tertiary heaths in south-east England and with various peats, if it is assumed that the observed inhibition of growth is linked directly with a substrate unfavourable to that phase of humus decomposition marked especially by activity of the mycorrhiza-formers. This assumption was the starting-point for the compost experiments here described designed to induce artificially a change in direction of humus decomposition and lead thus to the production of a more favourable rooting medium. As evidence of the correctness of the general conclusions, importance is attached to the strikingly dissimilar results yielded by different composts of closely similar origin and nutrient composition in the same soil, and by the same compost in different soils and with distinct tree species. The significance of the experimental results is regarded as bound up with an application of these conclusions to given soil conditions, and not with the use of any particular compost as a direct stimulant to growth. Viewed thus, they can be compared directly with those following modifications of the litter constituents in woodlands by addition of slashings, mixed plantings, &c., and are offered as a contribution to the elaboration and extension of such measures in forestry practice.

The investigation described in this paper and in that preceding it had as starting-point the difficulty experienced in establishing pines on certain poor soils in south-east England. The attempt to relate the abnormal mycorrhizal relations there observed with definite soil conditions and likewise with a wider series of observations, had as secondary objective the desire to bring the results of experimental inquiry within the scope of silvicultural practice. The permanence or otherwise of the activation of soil processes now described and the associated effects on tree growth ascribed to them require the test of time.

In view of the complexity of the underlying soil problems and the vast literature concerning them, the attempt to relate these observations with a general hypothesis of changing humus conditions has been made naturally with some diffidence. The point of view behind the earlier observations was influenced by the works of P. E. Muller and by those of Falck (1). Although the role assigned to the mycorrhizal fungi of trees does not coincide with that suggested for mycorrhiza-formers in general by Romell, it appears that the observations and experiments now recorded with the hypothesis founded on them can be fitted into a scheme such as that suggested in this author's recent paper, 'Ecological Problems of the Humus Layer in the Forest'. Romell's hypothesis respecting the soil activities of the mycorrhizal associates of *Calluna* and species of *Vaccinium* appears to be offset by evidence that the fungi concerned are potential nitrogen fixers; likewise by the known reactions of the host plants to nitrogenous fertilizers. It is possible that prevalence of these plants as members of the ground vegetation favours persistence of mor in some other way. In the heath soil now under consideration, the scanty ground vegetation is dominated by *Calluna*, although even in this species, the mycorrhizal relationship, as deduced from structural features, is not quite normal.

To apply the view of mycotrophic activity put forward by Romell to the mycorrhizal associates of young pines would be directly at variance with the experimental results now described and with the interpretation placed upon them.

A traditional atmosphere of controversy envelops attempts to unravel the tangled skein of mycorrhizal relationships. The habit is so widespread among vascular plants, and its expression in different groups so varied, that contributions to the elucidation of the problem as a whole are necessarily fragmentary. No apology is offered, therefore, for placing on record in its present incomplete form the evidence for attaching special importance to the effects produced on the substrate by the mycorrhiza-formers of certain coniferous trees. It may be profitable to extend this view-point to other trees of similar mycorrhizal habit, or even to groups for which a relationship very different from that in trees has been assumed.

Acknowledgement is due to the Forestry Commission of Great Britain for a grant to defray the expenses of the work here described. It is a pleasure to acknowledge also the collaboration of the Research Department of the Commission and the unfailing courtesy and assistance of the administrative staff, in particular that given by the Deputy-Surveyor of the New Forest, Mr. D. Young, and his staff.

My thanks are due also to the Council of Bedford College, University of London, for the grant of a laboratory, and to the Department of Botany for the exceptional facilities provided. I am greatly indebted to Dr. I. Levisohn for continued laboratory assistance.

## IV. SUMMARY.

1. The paper gives an account of certain organic composts and the growth effects produced by their use on seedlings of three species of pine.

Comparative growth records after three years are supplied as graphs showing average heights and height-frequencies in control and treated populations in field plots, with dry-weight records for the corresponding pot cultures.

2. The conclusion is reached that the use of these composts as described, by modifying the course of humus decomposition, brings about qualitative changes in the organic constituents of a soil deleterious to tree growth, whereby the resultant products become markedly beneficent to the nutrition, growth, and mycorrhizal development of young conifers.

3. Evidence is presented that the action of the composts differs essentially from that of manures containing significant additions of available nutrients.

4. The experimental results are discussed in relation with current biological theories of soil ecology and the mycorrhizal habit in trees.

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## EXPLANATION OF PLATES

PLATE I. Experimental field plots at Wareham Forest, Dorset. Scots pine, sown April 1933, photographed July 1935.

Fig. 1, control plot, untreated; fig. 2, plot treated 10 lb. compost C 1; fig. 3, plot treated 10 lb. compost C 5. All from more exposed area.

PLATE II. Experimental field plots at Wareham Forest, Dorset. Corsican pine: sown April 1933, photographed July 1935.

Fig. 4, control plot, untreated; fig. 5, plot treated 10 lb. compost C 1; fig. 6, plot treated 10 lb. compost C 5. All from more exposed area.

PLATE III. Experimental field plots at Wareham Forest, Dorset. *Pinus contorta* var. *murrayana*: sown April 1933, photographed July 1935.

Fig. 7, control plot, untreated; fig. 8, plot treated 10 lb. compost C 1; fig. 9, plot treated 10 lb. compost C 5. All from more exposed area.

PLATE IV. Experimental field plots at Wareham Forest, Dorset.

Fig. 10, Scots pine: sown April 1933, photographed July 1935, plot treated 10 lb. compost C 8; fig. 11, Corsican pine, sown April 1933, photographed July 1935, plot treated 10 lb. compost C 8; fig. 12, *Pinus contorta* var. *murrayana*, sown April 1933, photographed July 1935, plot treated 10 lb. compost C 8. To compare with control plots, figs. 1, 4, 7. All from more exposed area.

PLATE V. Condition of roots in controls and plants treated C 1 and C 5 respectively: figs. 1, 2, 3, from field plots, Wareham forest; figs. 4, 5, 6, from pot cultures of same soil.

Fig. 1, Scots pine: roots of control (CO) and plants treated C 5; fig. 2, Corsican pine: roots of control (CO) and plant treated C 5; fig. 3, *Pinus contorta*: roots of control (CO), and plant treated C 5. In field plots treated C 1, the root systems were similar to those treated C 5.

Fig. 5, Scots pine: roots of control (CO) and plant treated C 1; fig. 6, Corsican pine: roots of control (CO) and plant treated C 1; fig. 6, *Pinus contorta*: roots of control (CO), and plant treated C 1. In pot cultures treated C 5, the root systems were similar to those treated C 1.

PLATE VI. European larch: pot cultures with soil from Wareham forest, Dorset, untreated and with additions of composts C 1, C 5.

Fig. 1, 7 months from sowing; figs. 2, 3, 15 months from sowing. Fig. 1 shows representative pots of controls (CO) and plants treated C 1 and C 5 respectively; at this age, condition within each series was uniform; fig. 2, representative pots of controls and plants treated C 5; all pots uniform within series; fig. 3, representative pots of controls and plants treated C 1, controls uniform in all pots of series; range of variations in treated plants illustrated.

## APPENDIX

*Chemical analyses of composts* C 1, C 4, C 5, C 7, *and* C 8, *showing percentage values for dry material.*[1]

| | C 1 | C 4 | C 5 | C 7 | C 8 |
|---|---|---|---|---|---|
| Total ash | 34·0 | 20·1 | 26·7 | 34·4 | 32·3 |
| Insoluble ash (siliceous matter) | 21·1 | 13·3 | 15·3 | 23·6 | 21·8 |
| Total nitrogen | 3·33 | 2·19 | 4·64 | 2·25 | 1·89 |
| Potassium oxide ($K_2O$) | 1·04 | 0·43 | 0·75 | 0·52 | 0·63 |
| Phosphoric acid ($P_2O_5$) | 0·77 | 0·28 | 2·80 | 0·56 | 2·15 |
| Ammonium salts | Absent | Absent | 0·21 | Absent | Absent |
| Nitrate nitrogen | 0·43 | No data | 0·15 | No data | No data |
| Fat | 0·3 | No data | 2·9 | No data | No data |
| Crude fibre | 10·1 | No data | 23·8 | No data | No data |
| $P_H$ of $\frac{1}{10}$ aqueous extract of wet material | 6·8 | 6·1 | 6·6 | 6·8 | 6·0 |

[1] Analyses carried out by Dr. H. E. Cox of Messrs. Hehner and Cox.

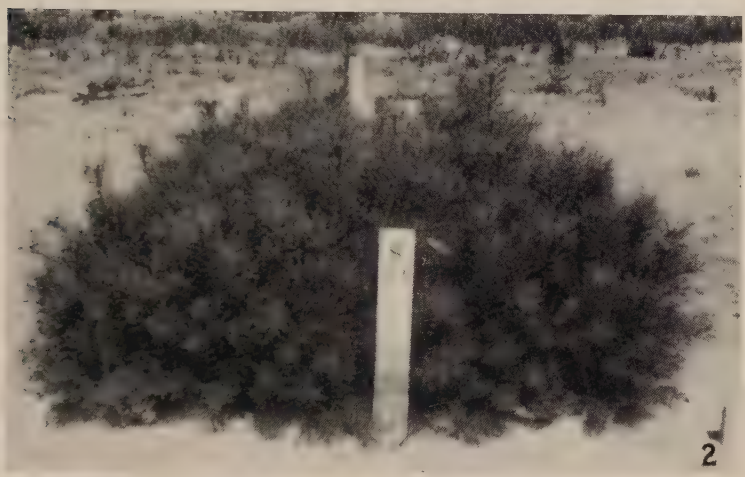


PLATE I

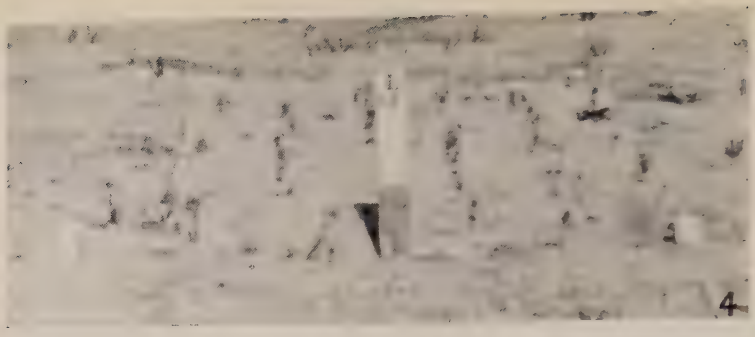
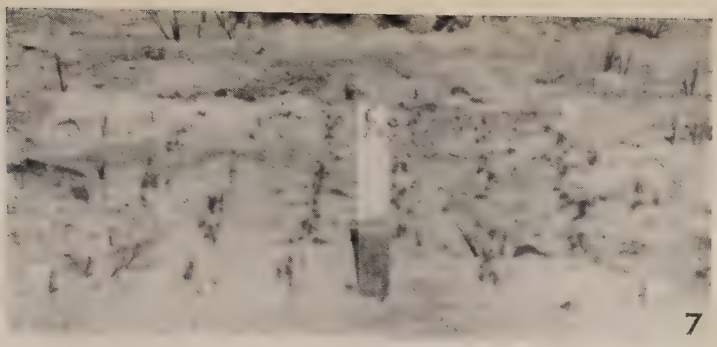


PLATE II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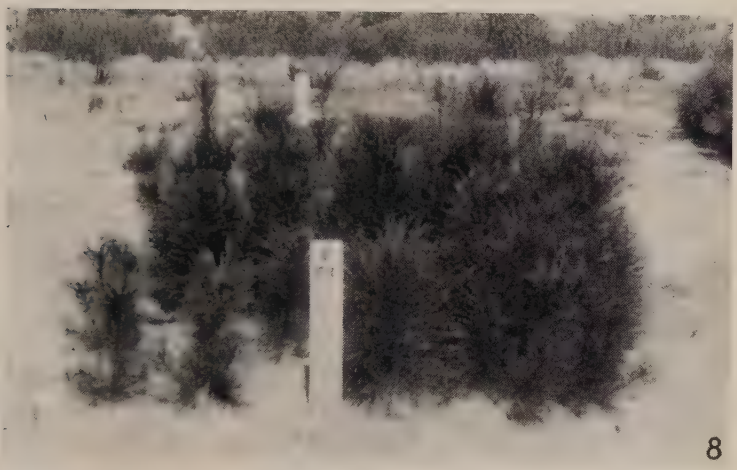
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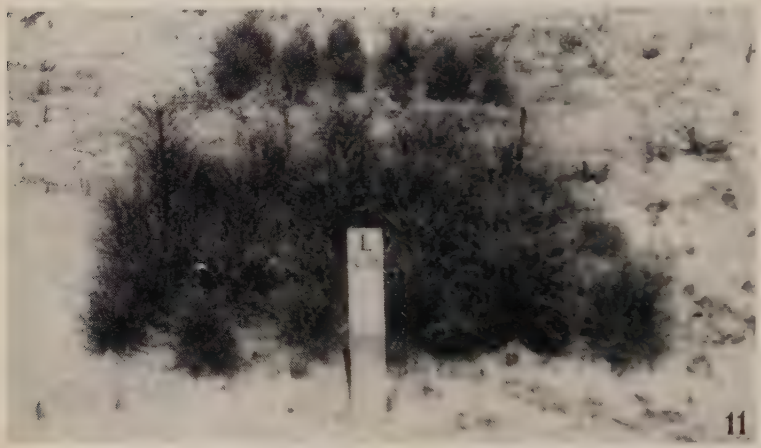

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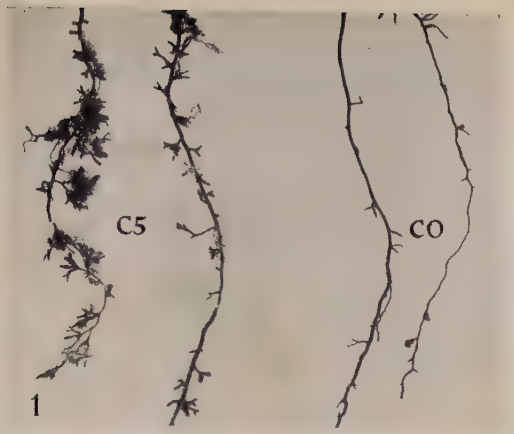
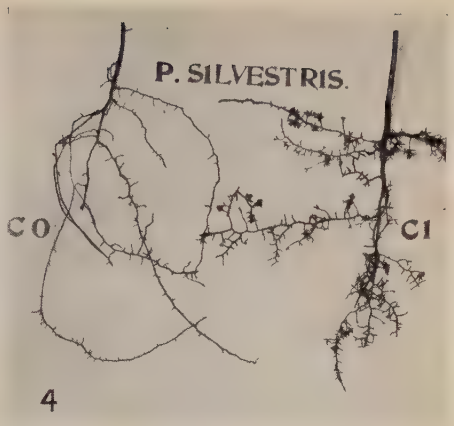
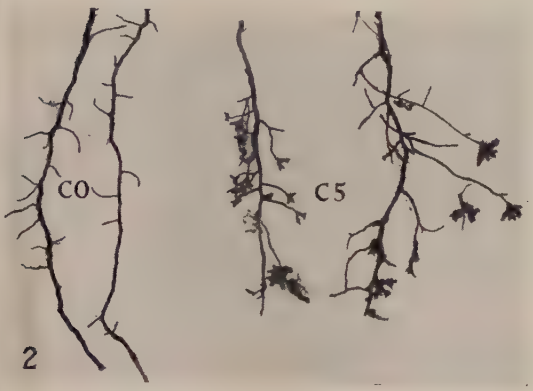
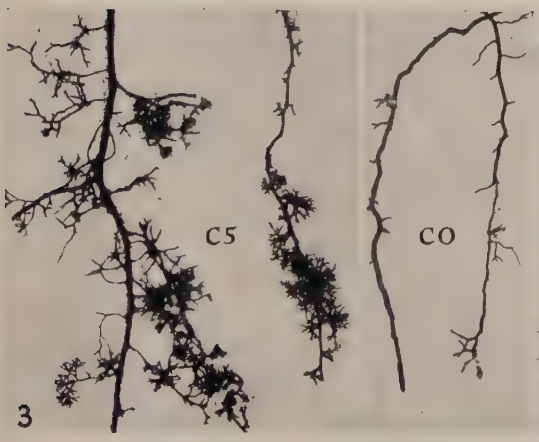

C5
CO
1


P. SILVESTRIS.
CO
C1
4


CO
C5
2

CO
C1
5


C5
CO
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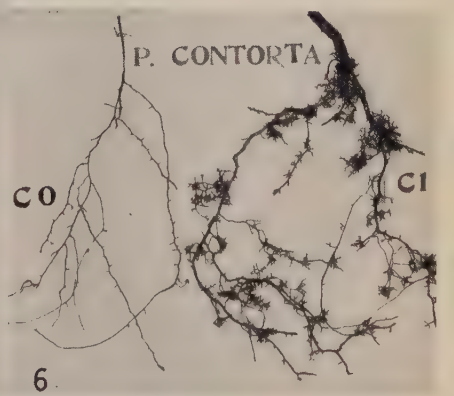
P. CONTORTA
CO
C1
6

PLATE V

LARIX europaea
23. 3. 34 - 23. 10. 34
CONTROL
C1
C5

1

C0
C1
C1
EUROPEAN LARCH
23. 3. 34. – 23. 6. 35.

2

C0
C 5
EUROPEAN LARCH
23. 3. 34 – 23. 6. 35

3

PLATE VI

# AFFORESTATION IN NEW ZEALAND

BY M. SUTHERLAND

(Dominion Museum, Wellington, N.Z.)

## INTRODUCTION.

WHEN the first occupation of New Zealand by the White Man began about 1840, the forests covered probably about 60 per cent. of the land area, and formed an obstacle to settlement which could only be removed by fire. Forest destruction and land settlement thus proceeded hand in hand, and within half a century it became apparent that the timber supply of the future was in jeopardy. Legislation soon was necessary, and, ironically enough, the first Forest Act embodied measures to ensure the planting of trees! The history of afforestation in New Zealand began in 1871, when the Bill for Encouragement of Forest Tree Planting became law, and applied to Nelson, Canterbury, and Otago provinces, where settlers were granted additional agricultural land in proportion to the number of trees planted by them. The first State afforestation activity was the formation, in 1896, of nurseries at Tapanui and Ewburn in Otago, followed in 1898 by the establishment of a nursery and plantation at Whakarewarewa, North Island. At the present time forestation is being carried on by the agency of the State, commercial timber-growing companies, local bodies and municipalities, and private individuals. Afforestation in this Dominion deals almost exclusively with the formation of forests of exotic species. Replacement of the indigenous forests by replanting of native species has so far only been attempted experimentally, and owing to the comparatively slow growth and exacting requirements of the timber species of the New Zealand rain forests, it is unlikely that extensive perpetuation will ever be accomplished by the direct operation of planting.

Conditions of soil, climate, and topography in New Zealand are extraordinarily favourable for timber growth, and native species supply a comprehensive range of woods of sufficiently high quality to meet the majority of domestic requirements. The greater proportion of indigenous forests are, however, over-mature, and consumption is not balanced by growth; to bring the remaining forests into a normal condition of sustained production will require a rotation period of not less than 100 years of silvicultural management, during which time continued demands on the timber must be met. A policy, therefore, has been adopted which aims to build up a sufficient area of rapidly growing exotic forests which will supplement the indigenous timber supply and tide over the period of scarcity. The programme laid down in 1921 provided for the formation of 300,000 acres of exotic forests and this has now been exceeded, hence the afforestation programme is being gradually reduced and activities are entering the era of silvicultural development and forest management.

Tree-growing operations are distributed throughout the Dominion, the

latest figures showing that the North and South Islands together contain approximately 720,000 acres of plantation, of which 406,179 acres are State areas, the greatest area being centred in the North Island. Most commercial and municipal operations have been modelled on the State procedure as far as establishment operations are concerned, and because, except for subsequent treatment, the methods involved were similar, it is proposed, therefore, to confine discussion in this paper to State activities only.

## TOPOGRAPHY.

The three chief islands which make up the Dominion extend over 13 degrees of latitude—the most northerly point being within 34 degrees of the equator —so that conditions vary from sub-tropical to sub-antarctic. The land surface is extremely broken, one main mountain system extending practically from north to south. The highest point of the range in the South Island reaches 12,349 feet in Mt. Cook and culminates in the North Island with the summit of Mt. Ruapehu at 9,008 feet. There are two great plains, the Canterbury Plain situated east of the Alpine Divide in the South Island, and the Central Volcanic Plateau of the North Island famous for its thermal activity; there is also the lesser Kaingoroa Plains which carry the most extensive continuous area of exotic plantations. The topography of New Zealand is sufficiently irregular to have an influence on the local distribution of rainfall.

## GEOLOGY.

The geological structure of New Zealand is still only partially determined, and the formations present a very irregular and confused sequence. Considerations of the nature and distribution of indigenous forests indicate that the actual geological composition of the tracts occupied are of secondary importance in relation to tree growth. Although this probably applies also to exotic species, it is impossible for this to be demonstrated at this early stage.

The formations of chief importance to the afforestation activities of the country are as follows:

1. The Mesozoic Rock System giving rise to 'Greywacke' formations from which are derived the shale-clay and the gravel soils widely distributed in the northern and eastern areas of the South Island and the southern portion of the North Island.
2. The main volcanic tracts of the North Island are comprised of the Rhyolitic rocks of the Tertiary and Recent Period which give rise to the extensive pumice soils of the Central Plateau.
3. The clays of N. Auckland are derived from Tertiary and Upper Secondary formations, with Rhyolitic outcrops forming volcanic loam soils.

## CLIMATE.

No locality in New Zealand is farther than 100 miles from the coast, and this proximity to the ocean produces an essentially maritime climate with no extremes between winter and summer. Although there are slight differences

in climate between the extremes of North and South, the climate is mild and equable throughout, with an abundant and well-distributed rainfall, while the country experiences no excess of solar heat. The North Island naturally has regions of higher average temperature than the South Island, but the maximum summer temperature limit in the south is not far below that of the Auckland region, and the mean maximum temperature for any month probably nowhere reaches 80° F., while in the South Island the mean minimum temperature only falls below freezing-point in the higher parts of Otago and Southland. Freezing up of the soil for long periods does not occur, and nowhere throughout the Dominion is there a longer period than 5 months with temperatures falling below 50° F.—the critical temperature for growth. Vegetation thus enjoys a long growing season, with a very short and mild resting season, but as seasonal changes are gradual, late and unseasonal frosts are prevalent. These factors have an influence on the growth and timber production of certain exotic species. In New Zealand snow lies for periods only above an altitude of 5,000 feet and the highest afforested area reaches to about 3,000 feet. Snow damage in young plantations and in over-dense crops has occurred, but this is confined to the higher areas, while at certain stations snow is unknown.

The average precipitation on plantation areas is about 50 inches per annum; the highest rainfall in New Zealand is recorded from Mt. Egmont, where it not unusually reaches 300 inches per annum, while the driest area occurs in Central Otago with 13 to 15 inches per annum, and the Canterbury Plains and eastern districts of the South Island record annual falls of 25 to 30 inches only. Nowhere is rainfall excessive, nor does the country experience prolonged droughts.

The annual rainfall and mean temperatures of the chief afforestation stations are given below:

| *Altitude, ft.* | *Station* | *Rainfall total* | *Temperature °F.* | | |
|---|---|---|---|---|---|
| | | | *Av. mean Max.* | *Av. mean Min.* | *Lowest Grass Min.* |
| 225 | Waipoua (Auckland Province) . . | 58·83 | 64·5 | 47·2 | 18·2 |
| 65 | Riverhead „ „ . . | 50·52 | 64·8 | 46·7 | 13·8 |
| 1,000 | Rotorua, North Island . . . | 51·23 | 65·0 | 44·6 | 19·2 |
| 2,125 | Karioi, „ „ . . . | 42·54 | 58·9 | 37·3 | 8·0 |
| 1,225 | Hanmer, South Island . . . | 41·01 | 60·7 | 38·1 | 4·5 |
| 743 | Balmoral, „ „ . . . | 23·07 | 61·9 | 40·8 | 9·0 |
| 900 | Golden Downs, Nelson, South Island | 39·82 | 61·7 | 39·4 | 9·0 |

NURSERY SYSTEM.

Large permanent nurseries were formed at the beginning of operations, and owing to the development and improvement of road transport both within and outside the plantations it has been possible until recently to continue

this system of centralized distribution. On the most extensive areas, as the planting operations moved farther away from the central nursery, large new nurseries were formed ahead of activities and were ready to distribute stock by the time planting reached their vicinity. Each nursery differed in altitude, in climatic conditions, and to some extent in soil quality, and these factors necessitated slight variations in the treatment of species and in the methods which were employed.

Two general methods of nursery production are employed in large-scale State operations: (*a*) growing of nursery stock in seed-beds, either open or protected; (*b*) raising nursery stock in open-field drills. A complete discussion of nursery procedure is beyond the scope of this article and it is proposed to give here only the bare outline of nursery practice and to indicate the principles involved therein. Growth of seedlings, in general, is more rapid in New Zealand than in European nurseries, and it is necessary to maintain stock in the nursery for only 2 years, although certain species require less or more time to reach plantable size. For many years it was the custom to shelter all seed-beds from the time of sowing until well after germination of the seed, using scrim-covered frames which gave protection to seedlings from excessive drying and sun heat. During the last decade this method has been discontinued, and now it is the custom to sow in protected beds only those species which are less easily germinated or are sun-tender as young seedlings, e.g. *Chamaecyparis lawsoniana*, *Pseudotsuga douglasii*, *Sequoia sempervirens*, *Thuja plicata*, and the Southern pines. Such species may require also an extra year in transplant lines. Seed-bed sowing is carried out about October and seasonal growth in the autumn ceases about March. Lining-out operations then proceed with the small-sized plants of Douglas fir, *Thuja plicata*, Redwood, and *Chamaecyparis lawsoniana*, any specially advanced seedlings being utilized for planting. Trees are normally left in transplant lines for only one year, and after 'wrenching' once or more in autumn and early winter are lifted and transported to the planting stations.

In the line-sowing method, seed is drilled in on cultivated land by means of an adapted Planet Hand Seeder, in a similar manner to ordinary field crops. This method is employed only for the hardier species of pines such as *Pinus radiata*, *P. ponderosa*, Corsican pine, &c., and it produces *Pinus radiata* ready to plant as one-year seedlings while the remaining species require two growing seasons in the nursery.

The large-scale operations thus possessed special features which were developed as adaptations to economical working conditions. Such was the simplifications of weeding operations by sowing seed in bed bands and in open lines (instead of broadcast beds) where weeding was carried out largely by machine instead of entirely by hand. A further innovation was the extensive use of seedling stock instead of transplants—this increased the 'wrenching' operations but diminished the necessity for lining out.

The stage has now been reached when absorption of huge nursery stocks by large-scale planting has come to an end and consequently nursery areas are

being reduced to a minimum sufficient to provide for beating up and for small planting programmes.

PLANTING AREAS.

The afforestation units are well distributed throughout the Dominion on different types of poor land unsuitable for agriculture. Many of these areas are remote from present large centres of population with consequently little means, under present conditions, for the economic disposal of intermediate returns. They represent various climatic types and soil conditions, which entail slightly varying methods of planting procedure; it will suffice, however, to describe briefly the main types of plantation units which, if grouped more or less with relation to their geographical distribution, represent roughly as many types of exotic forests. Each type exhibits distinct local characters, but differs finally very little from one universal model. The areas may be roughly classified according to the nature of the soil and of their vegetative covering which necessitates different degrees of land preparation.

1. *Manuka Scrub Land.* This is a widely distributed ecological type occurring on all classes of soil from the north to the south of the Dominion. Such areas are covered by almost pure scrub of *Leptospermum scoparium* and *L. ericoides*, reaching on an average to 8–12 feet in height, but fine leaved and allowing a fair proportion of light to penetrate to the ground, which is either carpeted with brown dead manuka leaves or a sparse cover of light grass or herb growth. Where manuka is growing freely and undisturbed it may reach an impenetrable thicket stage, while in the higher altitudes and poorer pumice lands short sparse manuka forms the main vegetative cover.

2. *Bracken areas.* A covering of *Pteris aquilina* var. *esculenta* constitutes the second land type and indicates, generally, a better soil quality than land under manuka. The old dead fern forms a dense mat upon the ground 2–3 feet deep, while fronds rising to 6 or 8 feet are the rule on some better areas, and such planted areas require constant attention.

3. *Tussock Grass Lands.* This grassland is characterized by the growth of grass in clumps or 'tussocks' of 10–12 inches height between which is open ground, and the trees planted on this acquire shelter from the surrounding tussocks. Planting on this type of country occurs mainly in Canterbury, Otago, and Southland, but is carried out also on the Karioi Plains, south of Mt. Ruapehu. The South Island areas are chiefly on low ranges of rounded hills clothed with 'tussock' composed of *Poa caespitosa*, *Festuca nova-zelandia*, and in higher areas of 'snow grass' *Danthonia Raoulii*, while bracken or manuka may occur on broken land or gullies. The North Island tussock country consists of gently rolling plains rising from 1,500 feet to 3,000 feet altitude. The climate on these areas is severe, cold winters with snow lying for days and early and late frosts occur, while summers are hot with a tendency to drought periods.

4. *Pumice Lands.* These lands offer great facilities for tree-planting operations, and extend roughly from north of the Thermal district, 60 miles south

over the Kaingaroa Plains to Lake Taupo, occupying a plateau between 1,000 feet and 3,000 feet altitude. This consists of a treeless plain cut up occasionally by rift-like dry gullies, and, as the land produces 'bush sickness' in stock, it is unfit for farming.

The vegetation is scanty, consisting of short sparse manuka, scattered plants of 'grass tree'—*Dracophyllum subulatum*, and the grey xerophytic shrubby 'tauhinu'—*Cassinia vauvilliersеii* with occasionally *Gaultheria* species. As the altitude rises these plants become sparser and the appearance of lichen on the soil surface is characteristic of poorer areas; predominating *Dracophyllum* is a very definite indicator of frost areas, where it is of no use to plant other than frost-hardy species, e.g. *Pinus ponderosa*, Corsican pine, or *P. murrayana*.

5. *Scrub Lands*. These include clay and gravel areas typical of the foot-hills in North Canterbury and of the lower Nelson ranges, and also the shingle plains of the eastern South Island. Manuka scrub covers such areas except in Nelson where bracken predominates, and on the foot-hills where open hill slopes occur above 1,500 feet altitude and are sparsely grassed with tussock formation. Remains of Mountain beech forest are present in the gullies which are excluded from planting operations, and in general the planting of these lands presents a harder problem than on foregoing types. Steep land is encountered at the higher levels, the soil dries out easily, being made up of 6–12 inches coarse shale clay or loam on rotten disintegrating grey-wacke rock, while on the flats a shingle layer overtops the soil.

6. *Gum Lands*. These areas, situated in the Coromandel and Auckland peninsulas, are typical waste gum land, and have been rendered thus by unsuitable clearance for settlement followed by close working over during gum-digging operations and continual soil leaching in the past. The soils are heavy hard clays poor in mineral matter, wet in winter, and periodically unworkable. The characteristic vegetation is bracken and manuka with various shrub species in the gullies. The manuka in places reaches tree form with stems up to a foot in diameter and height varying up to 20 feet. On poor open areas or where manuka is sparse and short, a short (2 feet) shrubby plant—*Pomaderris edgerleyi*—comes in as low ground cover.

### PREPARATION OF LAND FOR PLANTING.

On bracken areas this consists of a preliminary autumn light burn, preceded where manuka is dense by line cutting in the scrub. Burning off the tussock lands prepares the land for planting by removing the dead grass mat from the surface and with the spring flush there is provided an open-tuft growth which merely acts as shelter to newly-planted trees.

In manuka areas it has been recognized that a thin scrub cover affords valuable shelter to the newly planted trees from wind and soil desiccation, and in order to provide suitable conditions access lines are cleared at 8 or 16 feet intervals across the block, and the area is then lightly fired.

Rabbit fencing must be constructed where necessary, and although the pumice areas are not fenced, systematic extermination of the pest over a new

area is necessary for a year at least before planting operations reach the area.

PLANTING METHODS.

All the older plantations up to 1920 were formed by pit-planting using chiefly 2- or 3-year transplants, but the more recent large-scale planting necessitated a more rapid and less costly procedure. In the light pumice soils T-notching with an ordinary spade is used, and planting often progressing across a mile of country while the direction of lines is checked periodically by poleing across the area. On the tussock, hilly, areas of the South Island, the tool employed is the mattock, which is used working up or down hill; the first insertion makes a perpendicular cut and breaks up the soil; a second cut, after insertion and firming of the plant, closes and packs the pocket. This method is of value in grassland where mere notching allows the sod to dry back and open along the cut. On the shales of the South Island, mattock was found to be quicker and more efficient than spade planting, but on the Nelson fern-covered hills with a stiff or gravelly soil spade notching is employed. In the wet sticky soils of North Auckland, a half-pitting method is necessary, the planter breaking up the soil considerably before inserting the plant—pre-pitting is only employed in exceptionally heavy areas.

SPACING.

The early planting was carried out at a spacing of 4 feet × 4 feet, and in 1916 density was decreased to 6 feet × 6 feet planting. It was presumably originally intended to follow European practice and thin these crops at an early age, but various circumstances prevented this and the State is now forced to solve the problem of unthinned, over-dense crops. The large-scale planting has been carried out on a standard density for all species of 680 stems per acre. The effect of this wide spacing is beginning to appear in some of the plantations now nearly 15 years old, and may necessitate further silvicultural treatment to counteract the excessive and persistent branch development. It is indicated that even with the fast-growing *P. radiata*, mutual cleaning is ineffective at this density, and artificial pruning of final crop trees may become necessary for the production of good-quality timber. The choice of a wide-spacing policy was largely influenced by considerations of the position with regard to disposal of future thinnings; the cots of thinning in over-dense crops already promised to be heavy, and the lack of outlet for the produce was then apparent. The aim, therefore, was to eliminate the usual first silvicultural thinning of small-size trees. Further trial and investigation is necessary to decide on the optimum density, from all aspects, of the various species in use.

AGE OF PLANTING STOCK.

The tendency of recent years has been to reduce the size of planting stock, and to use seedlings rather than transplants; this is partly due to the adoption of open-line nursery methods. *P. radiata* is now planted as seedlings, and those

grown in North Island nurseries are ready at 8 months to plant out as 8–12-inch seedlings, usually twice wrenched. Two-year seedlings of Douglas fir make excellent planting stock, but owing to danger of grass grub (*Odontria* species) attack this species is not left in beds, but 1-year seedlings are lined out, and as 1+1 make ideal planting stock of an average height of 7–10 inches. Corsican pine and *P. ponderosa* stock raised in open drills in both North and South Island nurseries are planted as 2-year seedlings which have been wrenched three or four times and have an average size of 4–6 inches height growth. *P. murrayana* plants make little growth in their first season, but grow rapidly in the second year, so that 2-year seedlings give normal stock. This species is used frequently to beat up areas of less rapidly growing pines, and for this purpose older and bigger plants are utilized. Species such as *Thuja plicata*, *Chamaecyparis lawsoniana*, and *Cryptomeria japonica*, used for planting on worked-out native bush areas or for underplanting, face keen competition with the regrowth of secondary under-scrub or with heavy blackberry cover, and for such areas large transplants are necessary, usually 2+1 or 1+1 trees being used. The Southern pines, *P. caribaea*, *P. taeda*, and *P. echinata*, are raised in North Auckland nurseries, and planted out as 1-year or sometimes 2-year seedlings, while *P. palustris*, planted as 2+1 trees, remains in the 'grass leaved' stage with little height growth for 3 or 4 years, although the root system is especially well developed. European larch is raised in seed-beds, and 2-year seedlings of size 10–12 inches are normally planted; as bracken areas are usually selected for this species, it has been found necessary frequently to use larger and older transplants.

SELECTION OF SPECIES.

From the beginning of tree-planting activities in New Zealand the native species were discounted—the aim was to get a rapid return, and for this purpose natives trees are not suited. As was natural, the choice of species in the early days fell upon those which were in favour in Europe for afforestation purposes during the latter half of last century. This selection offered trees from European localities varying from a Mediterranean climate to northern Scandinavia, and from both eastern and western regions of North America. The climate of New Zealand differs fundamentally from any of these, so that the introduction of each species has meant a complete adaptation to new conditions. The oldest State plantations being now 35 years old, the selection of species has actually passed the first experimental stage, and it is apparent which species have become established and which have failed completely. But at this stage, probably less than half-way through the necessary rotation, it is still not possible to assess the quality of the final crop, and present judgements may have to be revised before maturity is reached.

Broadly speaking, the following species may be judged from present indications to be the successful trees for commercial timber growing.

*Pinus radiata*. Planted on suitable sites *P. radiata* is successful throughout the Dominion, and has become the most universally planted exotic tree both

for shelter and general utility. Growth is extraordinarily rapid, and timber from trees less than 50 years old has been utilized for house-building purposes; as a rule most of the timber used commercially up to the present has come from shelter belts and from singly grown trees and is of small dimensions, but the quality of timber from future plantation-grown crops may presumably be expected to improve. Utilization of main-crop trees and the larger thinnings for case wood or for small-dimensions building timber has now become possible in plantations of 25–30 years, and the indications are that *P. radiata* on all but very best sites will require to be grown on a short rotation of 25–30 years. Certain limitations to the growth of this species are becoming manifest in the plantations grown on the medium and poor sites of most of the areas. It will not flourish under severe climatic conditions as on higher pumice country, but suffers from the effects of prolonged heavy frosts and snow which cause a breaking down or cracking of heavy branches and flattening of the rapidly drawn up stems in close crops. *P. radiata* will not grow on excessively wet sites, and even when well grown it cannot stand prolonged drought conditions which are apparently favourable to the attacks of *Diplodia* disease. Shallow soils on a shingle sub-layer are showing themselves unfit to support the continuous growth of rapidly growing trees, while poor growth is obtained on pan soils, especially if they are liable to drought. *P. radiata* exhibits an interesting 'form' problem since there exist in the plantations side by side, and to all knowledge raised from the same seed, a series of trees varying from the tall growing, sparsely limbed and light-foliaged type with large cones, to the rough, heavily branched, coarse-leaved, undesirable tree with short cones. It regenerates freely and crops of at least a third generation exist in the country.

*Pseudotsuga douglasii* is preferably chosen for fern country and for medium and good soil sites, except those with high frost incidence. It is thriving under both North and South Island conditions and in the first 30 years on suitable soils yield comes second to *P. radiata*. As in European plantations, stem selection within the crop starts early, and it has been shown in growth studies that diameter classes in unthinned stands of about 30 years cover a wide range with heavy suppression of the lower-sized trees which hang on for a long period just alive. Most of the measurable crops were planted at 5 feet spacing, and this is probably too heavy a stocking, although some extraordinarily clean, even-grown timber has been produced under these conditions. The relation of sap to heartwood at 30 years is about 2 to 3, but it is possible that the later growth of the rotation may produce good quality timber. Regeneration takes place freely in several localities from 30-year-old trees, and New Zealand grown seed is now utilized in State activities.

*Corsican pine* was planted among some of the earliest crops, and the growth of this species has justified its choice. On hill sites outside of Auckland Province, this species takes fifth place in the relative volume yields of the standard species. In the first 10–15 years growth is slow but steady, and from this period diameter growth increases rapidly. On the whole, Corsican pine of older crops has a good stem form, but in the first 15 years the ease with which

crowded stems become totally suppressed allows of the development of a large proportion of 'wolf' and misshapen trees, and it is the writer's opinion that light early thinning is essential to obtain an even crop in this species. A sample plot of 31 years measured (10 years) after thinning exhibited a fairly even diameter crop in contrast to a 20-year-old untouched crop of the same original spacing, where wolf trees, surrounded by half a dozen dead or dying suppressed stems, formed approximately 10 per cent. of the crop. Heartwood forms extremely slowly, and it is questionable at present whether the timber produced in an average rotation of 80 years will be of an economically high quality.

*Pinus ponderosa* has proved itself in the State plantations as far as adaptability to difficult conditions and volume growth are concerned; timber quality is as yet unproved. This species is now always selected for afforestation of cold and frosty, poor soil sites; apparently soil conditions do not influence growth to any great extent since *P. ponderosa* is growing vigorously on nearly all soil sites except swamp, from about 38° latitude to the southern extreme of the Dominion. Probably owing to mixed seed consignments in the past, there may be found in the plantations types ranging from the light-branched, rapidly growing, long-needled form designated as *P. benthamiana* to the slow dirty-growing, short-needled variety approaching *P. scopulorum*.

*Pinus murrayana* forms a very small proportion of the older plantations, but is being increasingly used now on sites similar to *P. ponderosa* and Corsican pine areas where it will stand severe climatic conditions. It shows rapid growth up to 25 years and forms an even, clean-growing crop, but no opportunity has arisen as yet to judge the quality of the timber. Its rapid early growth makes this species of extreme usefulness in filling up open crops, and its chief use will probably be in interplanting under-stocked areas of slower growing species.

*European larch* was extensively planted during the first 20 years of the planting activities, both pure and as a constituent of many mixtures, in suitable and unsuitable locations. The results on the latter sites are now evident in certain worthless blocks on frosty flats where the elementary principle of European foresters of growing larch on its natural hill slopes was disregarded.

Lack of thinning in close grown larch on poor and medium sites in general produces an uneven crop of universally low-class trees, but on good sites, where conditions are suitable for this species, natural selection is producing in crops of 30 years a fair proportion of Class 1*a* trees, together with well-developed co-dominant, Class 2 trees, the greater number of the remaining crop being in Class 4 or totally suppressed. So far larch disease has not appeared in New Zealand, nor is this species subject to the insect attacks common elsewhere. On the hill slopes of shale clays in Southland vigorous regeneration of larch flourishes from seed trees 21 years old.

*Japanese larch* was planted as trial areas on frost-free slopes on pumice land at Rotorua, on shale clay at Hanmer, and on shale loam at Tapanui. On the first two sites the crop shows less growth than on poor sites in Britain; the

Tapanui crop, however, at 27 years, has given yields just slightly less than comparable European larch on the same site.

*Pinus strobus*. This was included among the early species, and though tried experimentally throughout, was successfully grown only in small plantation areas chiefly in the pumice districts.

During the period of early growth the fear has always been present that the crop might be attacked by blister rust, but plantations now 25 to 30 years old are clean and vigorous, and with the utilization of native-grown seed in the future, this species gives promise of being of greater importance.

Natural regeneration from trees 25 years old has occurred in a heavily thinned plantation at Waiotapu, although light and soil conditions were unsuitable for survival of the seedlings.

*Chamaecyparis lawsoniana* has been increasingly utilized in the last 10 years for under-planting and for re-stocking areas of worked-over indigenous forest, while on the wet 'pakahi' areas of Westland this species is replaced by *Thuja plicata*, which appears to be thoroughly adaptable to the poor, wet, soil conditions prevalent there.

On the North Auckland stations European species have not established themselves well, and at the present time planting includes a large proportion of the Southern pines of America. Indications from several years' trial plantations of *P. caribaea*, *P. echinata*, and *P. taeda* show that growth is rapid from the start and maintained vigorously up to 10 years at least, while *P. palustris*, which hardly makes any height increase for the first 4 years or so, then grows vigorously in height with little or light side-branch formation.

*Sequoia sempervirens*. Planted at wide spacing in mixture with European larch or with Austrian pine, Redwood has shown itself capable of far outstripping these species in height and volume growth, but the necessary optimum sites are limited to the better pumice lands at an altitude below 1,000 feet or in Nelson to bracken hill slopes up to 1,000 feet, but it is doubtful if this species will ever form extensive commercial crops.

Several minor species, from point of area, which show promise of forming economic crops are *Cupressus macrocarpa*, *P. muricata*, *Populus serotina*, and other species, while *Eucalyptus* species have been planted at Rotorua, and at farther north stations, and a few species give promise of producing useful hardwood poles of small size, or sawn timber.

In contrast to the few species which may now be regarded as entirely suitable for forest growing in this country, there are species which have definitely proved failures. Of European species, Austrian pine, which was formerly extensively planted, has made slow growth, and in many blocks where it formed alternate rows with *P. ponderosa*, Corsican pine, or European larch, it has practically gone out in 25 years. Pure blocks have stagnated and a rough tree type is prevalent. Scots pine early showed its non-adaptability to New Zealand conditions; the effect of a short resting season and humid conditions exactly opposite to its native habitat, together with the probable lack of a suitable mycorrhizal fungus in New Zealand soils, would appear to be the

explanations of the complete failure of *P. silvestris* in plantation, although fairly good individual trees are met with, mostly in the South Island. Norway and Sitka spruces are non-productive species, possibly partly because, in contrast to larch, planting sites in most cases on State areas have been chosen on dry slopes rather than damp flats. Small areas of Sitka spruce, where planted on the flat, exhibit delayed growth very similar to that on peat areas in Europe, and examples are to be seen where increment growth, delayed for 25 years, is now speeding up. Large blocks were planted with *P. ponderosa* var. *scopulorum*, and this species naturally has proved an absolute failure; 30-year crops exhibit height growth of 10 feet and these areas have now been replanted to true *P. ponderosa* or *P. murrayana*.

European hardwood species have proved unsuitable for afforestation in New Zealand, plantation soils and sites in general being too poor, although on optimum sites in Nelson and the Auckland Province, oak and Spanish chestnut grow rapidly. In certain of the better sites sycamore, in mixture with conifers, has held its own and acted as a soil improver, and in the absence of a better broadleaf species it may prove of value in this connexion. European beech cannot here fulfil the function of a broadleaf soil restorer and the question of preserving or restoring soil quality in the coniferous plantations remains unsolved as yet. All exotic broadleaf species except sycamore have proved useless in this respect and it may be necessary to investigate the silvicultural possibilities of some rapidly growing humus-forming native species.

WEEDING.

Except in fern areas, the preparation given to the land leaves it sufficiently clean to allow untrammelled tree growth for the first critical years. On bracken areas, however, even after a favourable clearing preparation, tree growth cannot keep pace with renewed fern growth and for the first 2 or 3 years the lines must be cleared annually to prevent loss of the trees.

SILVICULTURAL TREATMENT.

The older crops of the State plantations were purely experimental, and, being on grown on land which formerly had no tree growth, they form the pioneer exotic crops; there is therefore no precedent for determining the most suitable treatment of such crops. These older forests form only a small proportion of the whole area of plantations, but until the latter part of the present decade no attempt was made at organized thinning, with the result that plantations have reached a condition of extreme stagnation and even in some instances retrogression. At present thinning is confined to the older age classes, although the first of the large-scale plantings are now nearing 15 years old and will soon demand treatment of some kind. Up to the present, there has developed no regular outlet for the disposal of thinnings, while the cost of thinning in untouched stands is high, hence the question of expediency arises with regard to present treatment and the following possibilities must be considered. With thinning overdue for 10 to 15 years, is it possible to treat

the crop now with silvicultural advantage to itself; or is it too late? If treatment is possible, will it, under present conditions, be economic? And lastly, if no further steps be taken and the work be left to natural selection, will the saving in expenditure compensate for the lack of crop increment and ultimate loss in value of the plantations?

The favourable conditions in this country produce particularly vigorous growth resulting in a strong side-branch development, and the dense crop conditions of the early plantings have not, as might have been expected, produced an early death and severance of these side branches. Rather the position appears to be that in some species the whole crop stagnates, while in others a large proportion of trees die early, which allows for the undue development of 'wolf' trees and stems of excessive side branching. The impenetrable mass of dead branches and foliage caused a very high fire hazard, and this factor, apart from silvicultural considerations, has justified recent expenditure on treatment. As a means of utilizing unemployed labour, gangs were engaged from 1929 onwards in the underscrubbing combined with 'cleaning' of the older blocks. The latter operation started with the removal of dead stems, but it soon became apparent that this was not sufficient to stimulate crop growth and accordingly plans were evolved to carry out a system of thinning in the living crop which would be fool proof as regards the unskilled labour available, might possibly bring in some return, and would benefit the remaining crop. Thus the somewhat arbitrary method of thinning by 'Selected Trees' was employed on a large scale in South Island stations. By this process, in every fifth row of trees *élite* trees were selected, roughly every fifth stem when suitable; these were marked with permanent paint and surrounding trees felled to favour this future crop tree. This method was a somewhat unsatisfactory compromise with economic conditions, and had the effect of leaving much of the plantation still untouched; it has therefore been superseded, and the present procedure has been evolved, based on silvicultural considerations. This operation consists of complete underscrubbing and removal of dead and suppressed trees, together with the liberation of selected *élite* final crop trees by the removal of necessary surrounding stems. Further, where thinnings can be disposed of economically, a heavier thinning is carried out in the co-dominant crop. For this type of thinning it is necessary to employ only skilled labour, and all marking, felling, and extracting is now carried out by the permanent forest labourers. Utilization of large-sized thinnings for case timber, &c., is in the initial stages in State forests, and probably until all older stands have been treated, the extent of thinning operations will be dominated by commercial demands for the produce.

PROTECTION.

Along with the creation of the plantation areas, there has developed specialized organization to deal with the various phases of forest protection. Attention was early focused on fire prevention and the present organization includes in its control measures the installation of telephone systems and

look-out stations, provision for the easy distribution of fire-fighting appliances and for rapid mobilization of fire-fighting forces, utilization of a constant patrol staff, and the maintenance by cultivation of several hundred miles of fire-breaks. The necessity for protection against disease and insect pests has arisen more recently, and the incidence of such dangers has developed along with the progressive change in the sanitary condition of the plantations. Certain epidemic diseases have developed in some of the older plantations, and the occurrence of these is governed by the following factors: over-dense crops, possible introduction of disease with imported seed, and lastly the menace of large blocks of pure species. On the whole, however, exotic plantations in New Zealand harbour a very small number of insect or fungus pests, and in the current establishment operations improved silvicultural methods and specialized inspection should eliminate many possible dangers. Animal pests consist of rabbits, opossums, and deer; the latter, while being so far kept in check in plantation areas, creating a dominion-wide and ever-increasing menace to forest growth.

## UNDERPLANTING IN INDIGENOUS FORESTS.

A form of afforestation which has only been lightly touched upon in this paper is that which is intimately bound up with the future management of cut-over native forest areas. In the last 4 years, underplanting of suitable areas of bush with certain exotic species has been adopted as a routine measure, the aim being to procure a short rotation exotic crop while supplementing the depleted stocking of the area until the young crop reaches maturity. Started experimentally 12 years ago, the experience thus gained has shown that successful establishment of *Chamaecyparis lawsoniana*, *Thuja plicata*, *Cryptomeria japonica*, and possibly *Tsuga heterophylla* may be secured when planting is carried out immediately following upon milling operations. When certain conditions prevail on the milled area, the exotic tree species are able to compete successfully with the regrowth of secondary shrub species. It is probable that this utilization of cut-over forest areas will increase in the future.

It is now possible to define the position with regard to exotic forests in the Dominion. Afforestation in New Zealand has in the last 10 years fulfilled the State policy of establishing a safety margin in the formation of supplementary forests, it has progressed beyond the initial state of forest formation, and these activities are now being gradually reduced to give place to the next epoch of management and partial utilization.

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## SUMMARY.

1. The rapid disappearance of forest consequent upon the settlement of New Zealand in the first half of last century led to the realization that the future timber supplies of the Dominion were threatened with extinction; and

FIG. 1. Type of country planted. Manuka scrub on the pumice lands, North Island, New Zealand

*Photograph by N.Z. State Forest Service*

FIG. 2. Cut-over Tawa-Podocarp forest, underplanted with *Chamaecyparis lawsoniana*, Akatarawa valley, Wellington Province, N.Z

PLATE VII

PLATE VIII

FIG. 3. Corsican pine on the pumice lands, Kaingoroa Plains, N.I., N.Z. Age 30 years, av. ht. 63·5 ft., av. diam. B.H., 8·6 inches. Thinned at 22 years

*Photograph by N.Z. State Forest Service*

FIG. 4. Douglas fir on pumice lands, Kaingoroa Plains, N.I., N.Z. Age 31 yrs., av. ht. 80 ft., av. diam. B.H., 10·1 inches. Heavily thinned at 26 years

*Photograph by N.Z. State Forest Service*

in 1896 legislation authorized the initial formation of State nurseries and plantations. The remaining areas of indigenous forests are over-mature and consumption is not balanced by growth. The policy adopted, therefore, is to bring these forests into a condition of sustained production and meanwhile to bridge the period before normal production is resumed by the formation of exotic forests to supplement the supply of native timbers.

2. Afforestation is carried out by the State, company, and municipal authorities, and by private ownership; and exotic forests now cover an area of many acres, located chiefly in the North Island. Since the State areas are typical for all afforestation operations throughout the Dominion, only State activities are discussed.

3. Climate throughout New Zealand is maritime, with no extremes, and a well-distributed rainfall. Seasonal changes are slow and result in unseasonal frosts; but winters are short and mild and vegetation enjoys a long growing season.

4. Planting is carried out on areas of poor soil type, and sites may be classified mainly according to the vegetation and hence the degree of preparation of the land for planting. Six types of areas may be distinguished: manuka scrub lands, bracken areas, tussock grass lands, pumice lands, scrub lands of the South Island, and gum lands of North Auckland.

5. Planting is carried out by either spade or mattock notching, and in heavy clays a more complete breaking-up of the soil is done at the time of planting, except where pre-pitting is employed in special situations.

6. Until 1921 planting was almost universally carried out on a 4 feet $\times$ 4 feet spacing, and over-dense crops now result. All of the big-scale planting has been formed on a density of 680 stems per acre. The age of planting stock varies with different species, the more common pines being put out as 2-year seedlings, while *P. radiata* is preferably planted as 1-year seedlings.

7. Results in the original experimental plantations are now apparent and have resulted in the choice of six species as standard successful species for current and future afforestation. Southern pines show great promise as the most suitable exotic crop for North Auckland conditions.

8. Lack of early thinning in the over-stocked crops has resulted in much stagnation in growth, and in 1929 unemployed gangs were employed in underscrubbing and cleaning in the older plantations, followed by an arbitrary method of 'Selected Tree' partial thinning. This method has now been replaced by routine thinning operations carried out by skilled labour.

9. Protection from fire has been organized from the start of operations, but has developed greatly under present conditions. The necessity for forest protection from disease and insect pests has arisen within recent years, and organization has been developed to meet the situation.

10. A form of afforestation is becoming of increasing importance with regard to utilization of cut-over areas of indigenous forests, where underplanting is carried out with certain shade-bearing exotic species.

# THE GROWTH AND QUALITY OF ENGLISH OAK

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## INTRODUCTION.

THE deservedly high reputation of English oak is due to the way in which it combines in almost ideal proportions a number of desirable technical properties. By reason of its strength, durability, and pleasing appearance, it is used for a variety of purposes and is judged by widely different standards of quality according to the particular use for which it is intended. The wide range of silvicultural conditions under which the timber is grown, coupled with the complex structure of the wood, accounts for the variation in the properties of English oak from different localities, and goes far to explain the divergence of opinion on the quality of the timber. As will be apparent from subsequent portions of this paper, the same qualities which commend a particular consignment of oak to one class of user detract from its technical value in the eyes of another, so that any expression of quality needs to be modified by an indication of the particular class of timber under consideration. Thus a parcel of oak specially selected for heavy constructional work would probably be rejected as unsuitable for joinery and cabinet-making, and vice versa, owing to the entirely different requirements of the two industries. It must be remembered that a large proportion of imported oak is intended for furniture-making and decorative work, and it is this class of timber which generally commands the highest price. Consequently, it is not unnatural that English oak is to some extent judged by these standards. It is natural, also, that the reputation of the home-grown timber should suffer by comparison with the high-grade foreign product specially selected for export in the countries of origin. Generally speaking, supplies of English oak as at present available are harder, heavier, and stronger than the selected joinery grades imported from the Continent, which probably accounts for the widely held view that English oak is unsurpassed for purely constructional uses by any oak grown elsewhere.

Structural examination of material obtained for a comprehensive investigation of the properties and uses of English oak at the Forest Products Research Laboratory has enabled certain broad conclusions to be drawn regarding the influence of growth conditions on the quality of the timber. The conclusions are limited by the fact that the experimental consignments were not specially selected with regard to the relations between tree growth and timber quality. Nevertheless they are considered worthy of record as a basis for further research and for their bearing on other investigations of a similar character. The material for the original investigation was drawn from a number of consignments ranging from Cumberland in the north to Wiltshire, Kent, and Sussex in the south, and selected to cover the variation in the quality of

standing oak timber available for utilization. The main emphasis throughout was on timber not of first quality, as the utilization of high-grade English oak is not a major problem of forest products research. Consequently the consignments did not include any selected butts such as are utilized in the form of veneers or for high-class cabinet work and panelling.

## PEDUNCULATE AND SESSILE OAK.

The scope of this paper is limited to the two native species, the pedunculate or common oak, *Quercus robur* L., and the sessile or durmast oak, *Q. sessiliflora* Salisb., together with the intermediate forms named collectively *Q. robur* × *sessiliflora* Gürke. The term 'English oak' is here used comprehensively in the above sense. Although the distinguishing morphological characters of the two species are clearly marked (3), no evidence has been obtained of any inherent difference between their timbers, any specific differences which may exist being masked by the variation due to external causes. It is known that each species has its own preference as regards soil and climate, so that pedunculate oak may be the more successful in one particular locality, while in another part of the country conditions favour the growth of the sessile form. The quality of the timber of each species varies so widely with conditions of growth that it is impossible to generalize on the relative merits of the two. Possibly the higher reputation of sessile oak for joinery and similar purposes is due to the fact that the exceptionally mild timber from Spessart, in Germany, is the product of this species. Spessart oak is characterized by remarkable regularity of growth and very narrow annual rings; the trees are exceptionally large and straight, having grown in close stand on a long rotation, in some cases of over 400 years (13). The probability is that under favourable conditions pedunculate oak would produce timber of similar quality, though its reputed tendency to a more regular branching habit would result in a shorter length of clean timber being produced. So far as the English timber is concerned, wood-working tests on both sessile and pedunculate oak from different localities have shown no reason for the former being preferred, and the present position may appropriately be summarized in a quotation from Laslett (10), who wrote in 1875, 'I feel bound to admit that during a long experience in working them I have not been able to discover any important difference between the two varieties.' The results of tests on other physical properties of English oak likewise indicate that no significant differences exist between the two species and, other things being equal, there is nothing to be gained by differentiating between them in practice.

## STRUCTURE OF THE WOOD.

The structure of a typical specimen of English oak is shown in Plate IX, fig. 1. The wood consists essentially of three distinct kinds of tissue: conducting or vascular, mechanical, and storage tissue. The cells composing the vascular tissue, namely vessels (or pores) and tracheids, have comparatively thin walls and wide lumina; mechanical tissue consists of thick-walled fibres;

and the function of storing food materials is performed by the parenchyma, consisting of thin-walled cells which occur in more or less scattered arrangement among the wood fibres, and also in compact strands of cells radiating from the centre of the tree in the form of rays. It is obvious that wood with an undue preponderance of vascular tissue is light in weight, while excessive development of dense mechanical tissue produces wood of high specific gravity. In a specimen of average growth rate, having about 12 rings to the inch, the springwood consists of a well-marked zone of pores, clearly visible to the unaided eye on a clean-cut section, embedded in soft tissue and forming a ring 2 to 4 rows wide. Usually there is a fairly abrupt transition to the summerwood, which consists chiefly of patches of fibres and soft tissue in varying proportions. The fibre groups give the cross-section of the wood a characteristic bright appearance, which is naturally more pronounced in dense specimens (Fig. 4). The summerwood pores are very small, and are embedded in irregularly fan-shaped patches of light-coloured soft tissue (tracheids and parenchyma cells) which contrasts with the darker fibrous tissue. Parenchyma tissue also occurs as somewhat diffuse parallel tangential lines of cells crossing the fibre groups, and in the form of rays. The latter are of two distinct sizes, the larger ones approaching 0·5 mm. in width, conspicuous on cross-section and separated by numerous small rays visible only with a lens. The broad rays are prominent on quarter-sawn or radial surfaces as lustrous bands or flakes producing the ornamental silver grain figure characteristic of oak.

Figures 1 to 4 illustrate the most important types of structural variation that occur in English oak. Figure 1 shows a balanced development of vascular, mechanical, and storage tissue. Figure 2, representing a very slow-grown specimen, shows the reduction of the summerwood in narrow-ringed material. In Figs. 3 and 4 two specimens of about the same rate of growth are contrasted; the preponderance of soft tissue in the one and of dense fibre in the other is a striking illustration of the way in which the relative development of different tissues affects the technical properties of the timber. Thus the density of a sample similar to that in Fig. 3 is about 40 lb. per cubic foot in the air-dry condition (about 15 per cent. moisture content), whereas timber of the type of Fig. 4 weighs about 50 lb. per cubic foot in the same condition. The average weight of English oak is midway between these two figures, but the lower limit of the range, as exemplified by Fig. 2, may be little more than 30 lb. per cubic foot.

### STRUCTURE AND PROPERTIES.

It will be apparent that variations in the gross structure of the wood (as distinct from the microscopic structure of the individual cells) are chiefly concerned with the relative development of vascular, mechanical, and storage tissue, and it is not difficult to see how these variations are correlated with differences in the quality of the timber. Owing to the ring-porous structure of the wood, the width of the annual growth rings (perhaps the most obvious structural feature to correlate with quality) is of importance in so far as it is

related to the proportions of springwood and summerwood. In slowly grown timber the balance between porous springwood and relatively dense summerwood is upset, so that the area of growth ring occupied by springwood vessels becomes disproportionately large. Extreme reduction in the width of the annual rings results in the summerwood being almost completely eliminated (Fig. 2). Wood of this type is soft, light in weight, and easy to work with hand and machine tools, and for these reasons is generally preferred for veneers and high-class joinery; it is not so suitable for purposes where strength or durability are of the first importance. Analysis of a large number of mechanical tests carried out at the laboratory has shown that there is a critical ring-width of about $\frac{1}{10}$ inch below which the strength tends to fall off, owing to the progressive elimination of summerwood fibres in favour of springwood vessels. In wood with rings wider than $\frac{1}{10}$ inch there is normally sufficient room for a balanced development of springwood and summerwood, and the properties of the timber are dependent rather on the proportions in which fibrous and vascular tissue are present in the summerwood zone. Thus, relatively wide-ringed timber with well-developed fibrous tissue is well adapted for constructional purposes or flooring, but is not so suitable for joinery or cabinet work on account of its hardness. The limitations of ring-width as an indication of quality are shown by a comparison of the two specimens illustrated in Figs. 3 and 4, to which reference has already been made. Although they have approximately the same ring-width the two specimens are obviously very different so far as the proportion of fibrous tissue is concerned. The same illustrations indicate how the structure of the wood is of practical importance in estimating the quality of oak by inspection. Examination of the end surface of a specimen that has been smoothed with a sharp plane or knife enables a rough visual estimate to be made of the proportion of dense summerwood fibres in the wood. The patches of fibre are generally discernible to the naked eye and are quite distinct under a reading glass or low-power hand-lens as roughly triangular areas of dark wood contrasting with the lighter, softer-looking tissues. The clean-cut end-surface of a specimen with a large proportion of dense fibres has a characteristic bright appearance in contrast to the dull surface of a sample with a low fibre content.

It may be mentioned here that the fibres of oak are of two types, the one with apparently normal lignified walls of moderate thickness and with a rounded lumen, the other with a thick inner secondary wall of gelatinous appearance, commonly with a crinkled margin to the lumen, which may be reduced to a slit or almost completely obliterated. The gelatinous-looking wall reacts to cellulose stains (e.g. chlor-zinc-iodide solution) and probably represents an abnormal state of development. Fibres with this type of wall tend to occur in the springwood and early summerwood; alternatively they may be of general occurrence throughout the growth ring or scattered indiscriminately among the normal fibres. They have been observed in greater or less abundance in most of the trees examined, but their distribution bears no apparent relation to their position in the tree. Investigations have so far failed

to establish the cause of this abnormal condition of the fibre walls. There is reason to believe that it has the effect of reducing the strength of the wood, as compared with that of normal wood of otherwise similar structure, and it probably has a corresponding effect on other physical properties as well. This belief is strengthened by the results of investigations on other species which exhibit the same abnormality.

GROWTH AND STRUCTURE.

In considering the influence of growth conditions on the structure and quality of the wood, the logical method is in the first place to examine the various ecological and silvicultural factors which together constitute the environment of the living tree, and then to attempt to correlate them with the structural features which ultimately determine the properties of the timber. It is rarely the case that a single growth factor is of supreme importance in determining the quality of the timber; factors interact to give an unlimited variety of growth conditions, and although in exceptional circumstances one factor may exert a dominating influence on the growth of the tree, under other conditions its effect may be almost completely hidden by the others. We are at a serious disadvantage in having very little fundamental knowledge of the way in which individual factors influence the formation of woody tissues. The material for the present investigation was drawn from a mixed lot of consignments scattered over a wide area, grown on different soils under different influences and methods of silvicultural treatment and, in short, unsuitable for an intensive study of the influence of individual growth factors on the structure of the wood. Consequently it was impossible to determine with accuracy the effect of any one factor, or indeed, to do more than draw certain general conclusions and indicate ways and means of approach to a more intensive study of the problem.

Guillebaud (5) has reviewed the silvicultural history of the average mature stand of English oak. Over-thinning at an early age has resulted in short-boled trees with spreading crowns whose lower branches have been suppressed and killed by the subsequent closing in of the canopy. It is abundantly clear that the low average quality of English oak timber is so largely due to faulty silvicultural methods that it is virtually impossible at present to correlate the timber quality with natural conditions such as climatic factors, soil characteristics, or water stagnation. Since the quality of the timber has been so adversely affected by the unsuitable treatment of plantations on what were originally good oak soils, it is evident that silvicultural methods constitute a factor of the first importance in the production of good-quality oak. Thus it may even be possible, by skilful silvicultural treatment, to produce better quality timber on a comparatively poor soil than is grown on a more favourable site where crop development has been neglected or mismanaged.

As regards the question of locality, it is fairly certain that the importance of this factor has been over-estimated in the past. While there is no question that under certain conditions a particular neighbourhood may rightly acquire

a reputation for producing oak of a certain definite character, it cannot be too strongly emphasized that geographical position is only one of a complex of variable factors, and for that very reason is not to be relied upon as an indication of quality. The significance of locality in affecting the quality of the timber can only be appreciated by inquiring further into the fundamental reasons for good and bad quality timber being associated with certain districts, that is, by analysing the factors of the locality.

Reverting to the influence of silvicultural factors on the quality of the timber, it is of interest to recall in the first place how the form of the tree determines the character of the wood which is being laid down at a particular period. Under similar conditions a tree with a short trunk and spreading branches will put on wider annual rings than one with a relatively tall trunk and a high narrow crown. The rate of diameter growth, as expressed by the width of the annual rings, is subject to a certain amount of control by silvicultural treatment, and in so far as the ring-width is related to the quality of the timber it is obvious that the silvicultural treatment of a stand, especially as it affects the spacing of the trees, may have a very considerable effect on the character of the timber.

A close connexion exists between the requirements of the tree itself for mechanical support and the character of the wood produced under various conditions; thus, the strong dense timber of an open-grown oak is specially adapted to withstand the mechanical strains imposed on it by reason of its exposed position, while the entirely different circumstances surrounding a tree growing in a densely stocked stand are reflected in the quality of the timber produced. Generally speaking, isolated oak trees growing in the open have a strong, hard type of wood (although at an advanced age there may be a change in the type of timber produced); on the other hand, long, straight-grained, mild timber of the kind that is preferred for joinery and cabinet work, is more characteristic of trees grown in close high forest.

The effect of external conditions on wood quality also depends to some extent on the age of the tree. The function of the trunk in the first place is to support the crown of the tree, and in early life the development of mechanical tissue (wood fibres) is apparently a matter of greater importance than the production of vascular tissue (vessels and tracheids) and storage tissue (rays and wood parenchyma). This state of affairs persists for a considerable period in oak, and appears to exercise a dominating influence on the quality of the timber for 30 years or more, according to circumstances, as shown by the dense character of the central core of wood in nearly all the trees examined. It is obvious that in comparatively small trees, 80 to 90 years of age, this central core forms a considerable proportion of the whole; in more mature trees, on the other hand, it is of less importance in determining the average quality of the log. For this reason, in comparing the quality of the timber from trees of different ages, the proportion of the logs occupied by the central core must be taken into account if misleading conclusions as to the influence of growth conditions on quality are to be avoided.

Although the abundant development of thick-walled fibres is attributed partly to the mechanical requirements of the tree, it is reasonable to assume that drainage and soil fertility may under certain conditions exercise a controlling influence on the production of the different types of tissue. In the United States (9, 11) investigations of the factors influencing the production of springwood and summerwood in certain coniferous species indicate that the production of summerwood is to some extent controlled by conditions of soil moisture and fertility. So far as is known, no work on these lines has been carried out on oak, and it can only be conjectured that here too excessive production of certain types of tissue is at least partly due to a lack of balance between the available nutrient constituents of the soil. In order to carry this problem a stage nearer to its solution it would be necessary to make it the subject of a special investigation on trees grown on selected types of soil, all other conditions being as nearly as possible the same for all the trees investigated.

Reviewing the results of the technical tests in the light of the foregoing considerations, it is of interest to see how far the outstanding characteristics of the various consignments investigated at the laboratory can be related to their silvicultural features. Wood-working tests showed the timber from Bedgebury, Kent, and Oakenhill in the Forest of Dean, to be mild in character and very nearly comparable with the best quality Continental oak. The Bedgebury trees were standards over coppice with an average of eleven rings to the inch; even the wider-ringed material of this consignment contained a relatively small proportion of dense fibre, which, in this case, for want of a better explanation, is presumed to be due to the soil conditions. The Oakenhill timber grew under conditions more nearly approaching high forest; available data are insufficient to show whether the slow rate of growth, resulting in the later formed timber being relatively soft and porous, is due to the restriction of the crown growth or to the unfavourable condition of the soil. Of the harder material employed in the woodworking tests, the trees from Brandon (Suffolk) were small, immature specimens, averaging only 76 years of age, so that the material under test consisted mainly of wide-ringed, dense wood of the quality usually formed in early life. Similarly, in working the timber from Walcot Park (Shropshire) the operator found that the dark-coloured, dense wood from near the centre of the logs was of an entirely different character from that laid down in later life when the trees were approaching maturity. The relatively poor quality of some of the Dean Forest oak (judged from the woodworking point of view) is probably due again to the trees being immature and at the same time too widely spaced, with the result that a large proportion of the stem consists of wide-ringed, dense wood.

Comparatively little variation was found in the strength properties of the timber from the four localities which furnished the bulk of the material for mechanical tests; taking specific gravity and resistance to crushing as an index of mechanical strength, the Wadhurst (Sussex) and Longleat (Wilts.) consign-

ments were classed as being slightly superior to those from Bedgebury and Walcot. From a consideration of the silvicultural records for the four consignments, the higher average age of the Walcot trees grown under high forest conditions is in accordance with a fair proportion of the wood from each tree being narrow-ringed and porous, which would tend to reduce the average strength of the consignment; and the fact that at least half of the Wadhurst trees were park grown would account for their timber being comparatively hard and dense. Otherwise, the field notes do not suggest any reason for expecting outstanding differences in the mechanical properties of the four consignments.

The main conclusion that emerges from this study is that oak may be grown to produce either of two distinct classes of timber. Generally speaking, oak that is acceptable for joinery and furniture should be slow-grown, although under certain conditions which are not known, comparatively fast-grown oak may be fairly mild and easy to work. On the other hand, oak for constructional purposes, where resistance to mechanical stresses is the outstanding qualification, requires to be fairly fast-grown. It is important that the quality of the final product should be taken into account in deciding the rotation and silvicultural treatment of oak stands. For the production of furniture timber, it will generally be advisable to restrict the width of the annual growth rings to about one-tenth of an inch—preferably less, and for this class of material especially it is important that the diameter increment be maintained at a regular rate, as the value of the timber is adversely affected by variations in structure. For timber intended for constructional purposes the growth rate need be limited only by considerations for maintaining the bole of the tree in good condition. This statement is open to modification according to local conditions of soil, but a considerable amount of field work combined with laboratory investigations will be required before definite conclusions can be drawn as to the effect of various soil factors on the fundamental properties of the wood.

SUMMARY.

1. No evidence has been obtained of any inherent difference betwen the timbers of *Quercus robur* and *Q. sessiliflora*.

2. The structural features of English oak are described with reference to the growth and quality of the wood. Variations in quality are largely due to the relative development of vascular, mechanical, and storage tissue, as determined by environmental conditions and the physiological and mechanical requirements of the tree.

3. It is considered that in normal circumstances silvicultural treatment has a stronger influence than natural conditions on the quality of oak. Further investigation is required to determine the influence of individual ecological factors on the structure and quality of the wood.

ACKNOWLEDGEMENTS.

The foregoing paper is based on a study of English oak which formed part of a more comprehensive investigation carried out at the Forest Products

Research Laboratory. I am indebted to Mr. W. A. Robertson, Director of Forest Products Research, for permission to publish the results in this form. The main conclusions are incorporated in Forest Products Research Records —No. 11.

A part of the early work on the structure of English oak in relation to its technical properties was carried out by Mr. J. C. Maby, formerly on the staff of the Laboratory.

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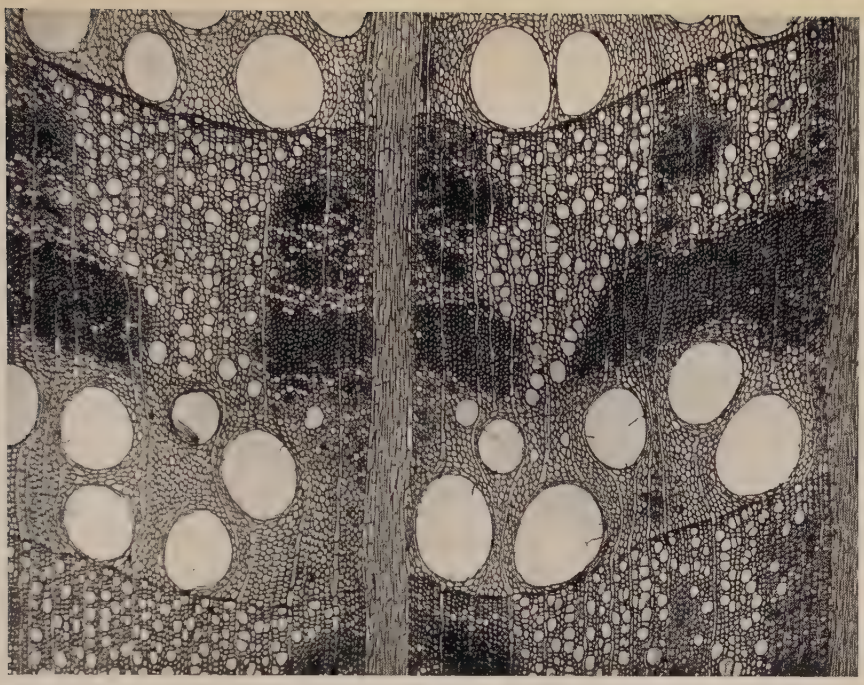

FIG. 1. Transverse section of English oak, showing the characteristic structure of the wood (× 35)

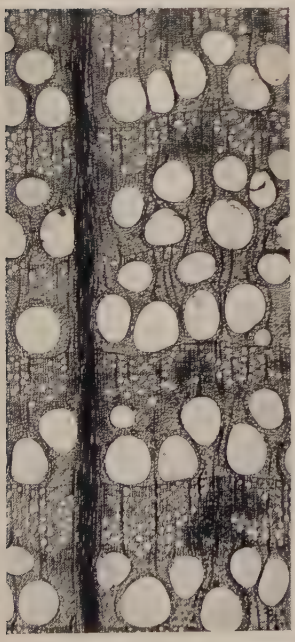

FIG. 2. Transverse section of a very slow grown specimen, showing reduction of the summerwood zone in narrow-ringed oak (× 17)

FIG. 3. Transverse section of a specimen with a preponderance of soft vascular tissue (× 17)

FIG. 4. Transverse section of a specimen with a preponderance of dense mechanical tissue (× 17)

PLATE IX

# INSECTS ATTACKING THE TIMBER OF ENGLISH OAK

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## INTRODUCTION.

OAK is attacked by a greater number of insects than any other English species of tree, and it is therefore to be expected that the timber of *Quercus* spp. is likely to show evidence of their attack, or itself become infested by a number of wood-borers. The majority of the insects which attack the growing tree are chiefly of forest importance and as such do not strictly come within the scope of this article. On the other hand, for the production of first-class timber, it is well to bear in mind that repeated attacks by such forest insects as defoliators, of which *Tortrix viridana* L., the oak leaf-roller caterpillar, is the most important, may, over a period of years, result in a loss in increment and thereby contribute to the production of inferior quality timber. Among wood-boring insects there are a number which attack the growing tree or green timber. Although many of these are comparatively unimportant, brief mention is made of them in the following notes to enable the timber merchant and those handling felled logs to distinguish the different types of damage, and to differentiate insects which are of little importance from those which may cause serious losses. A summary of the important types of defect due to insect attack is given in the Appendix (see p. 57).

## INSECTS ATTACKING GREEN TIMBER.

### I. *Coleoptera* (*Beetles*).

(*a*) *Bark-beetles—Scolytidae*. These insects breed in the bark of newly-felled logs and standing trees not in full vigour of health; the species commonly found in oak are comparatively few. The adult beetles excavate tunnels in the bark during the summer months, producing quantities of bore-dust, and deposit their eggs within these galleries. The young grubs or larvae, which in due course emerge, feed in the bark, or between the bark and the sapwood. The insects do not penetrate the timber and therefore do not cause any damage to it. The larvae are small, white, curved, legless grubs with brown heads and strong jaws. When fully grown they measure about 4 mm. in length. An account of the British bark-beetles and their importance in forestry practice has been given by Munro (9). The following are the two species most commonly found in oak in Great Britain:

*Scolytus intricatus* Ratz. (L. 3 to 4 mm.)

Excavates a short horizontal or transverse egg tunnel; larval tunnels long. According to Fowler (7) southern in its distribution in England; usually of secondary importance.

*Dryocoetes villosus* F. (L. 2½ to 3½ mm.)

Cuts its egg tunnels in thick bark; bore-dust fine in texture and always brown. Associated with fungus-attacked trees and of no economic importance; does not occur in Scotland.

(*b*) *Pin-hole Borers—Platypodidae and Scolytidae.* There are a number of insects of considerable importance to the timber user, differing from the true bark-beetles in life-history and mode of feeding but somewhat similar to them in size and appearance. These insects penetrate the bark and excavate in the sap and heartwood tunnels from which the bore-dust is usually entirely expelled. Their eggs are laid within the tunnels; the young larvae do not bore in the wood but derive their nourishment from fungi, which grow on the walls of the galleries and have been given the name 'ambrosia'. These fungi may produce a dark discoloration in the tunnels, and frequently a streak or stain is associated with the pin-holes, extending for some distance in the wood on either side of them. The borings (Plate XII, fig. 1) of these ambrosia beetles or pin-hole borers when abundant may produce serious defects in the converted timber. This type of insect damage is of greater importance in tropical timbers than in home-grown woods. The insects attack only green timber, occasionally sickly standing trees, but more frequently felled logs. The moisture present in green timber is necessary for the development of the fungi upon which the insects feed. As the timber seasons and the moisture content decreases, the fungus can no longer grow and the insect dies; in other words, pin-hole borers will not attack seasoned timber.

In order to prevent infestation by these insects, rapid extraction, conversion, and seasoning of timber are the methods advocated. Kiln-seasoning will at once destroy the insects, whilst during air-seasoning it is essential that the timber be stacked with stickers allowing adequate air-space between individual boards. If close-piled without stickers, green boards, sawn and stacked during the summer months, are liable to infestation by some species of pin-hole borers in Great Britain. Storage in water is also a method of restricting this type of injury. Timber is liable to infestation by these and other wood-boring insects only in spring and summer, since during that period the adults are to be found in flight. In the winter the majority of wood-boring insects are in the larval stage or, if in the adult condition, are hibernating and incapable, therefore, of extending the range of their attack.

The following are the species occurring in oak in this country:

Platypodidae—

*Platypus cylindrus* F. (L. 5 to 6 mm.)

The largest of the British species of pin-hole borers and the most important economically in Great Britain. The beetle attacks sickly standing trees or felled logs and cuts its tunnels (Plate XII, fig. 1) deeply into the heartwood. Fully-grown larvae, although closely resembling those of the bark-beetles, have a characteristic appearance, being apparently humpbacked because of the prominent prothorax. The bore-dust produced by

the adults is characteristic of this species and consists of fibrous fragments of wood markedly different from the dust of much finer texture produced by other pin-hole borers.

Scolytidae.

*Xyleborus saxeseni* Ratz. (L. 2 to 3 mm.)

*Anisandrus dispar* F. (L. 2½ to 3½ mm.)

These insects cut their tunnels in the heartwood of sickly or dying trees, and are widely distributed throughout southern England. According to Munro (9) they are of minor importance.

*Trypodendron domesticum* L. (L. 2½ to 3½ mm.)

*Trypodendron quercus* Eich. (L. 3 to 3½ mm.)

Egg tunnels are cut by the adult beetles in the sapwood. The larvae live in cells excavated in the wood, above and below the main tunnel made by the adult beetle. The arrangement of the system of tunnels made by the species of *Trypodendron* presents a ladder-like appearance when exposed in attacked boards, on conversion.

The above species of pin-hole borers are more or less unimportant in England, but in oak imported from America and Europe the *Xyleborus* beetles, of which there are a number of species, may cause considerable damage.

(*c*) *Longhorn beetles—Cerambycidae.* Although the majority of this group of insects live in green timber, there are a few species which can develop in dry wood. They attack in some cases the living tree, in others, sickly trees, while in others again, felled logs with the bark on are suitable for their development. The adult beetles are large, conspicuous, and easily recognized by their long horns or antennae. The eggs are laid in or beneath the bark according to the species, and the larvae bore between the bark and the wood, but in some instances may penetrate the sap and even the heartwood. The tunnels produced by the larvae are much larger than those made by the pin-hole borers and bark-beetles. They vary in size and length according to the age and species of the insect and are usually filled with closely packed bore-dust in the form of finely divided wood particles or fibrous shavings. The larvae (Plate XI, fig. 1) are elongate, fleshy-white or yellowish-white grubs with the body showing a number of segments and tapering slightly from front to back. Many are legless, but some have a pair of very short legs on the under-surface of each of the first three segments behind the head. The grubs vary in size with age, but when fully grown range in length from 1–10 cm. according to the species.

Control measures to prevent infestation of green timber by this group of insects are similar to those recommended for the prevention of pin-hole borer injury and consist of good silvicultural practice, quick extraction, conversion and seasoning, barking of newly felled logs or storage in water. The following are the species most commonly found attacking oak logs which are green or decayed by fungus, and in a moist condition:

*Clytus arietis* L. (L. 7 to 14 mm.)

*Clytus arcuatus* L. (L. 10 to 17 mm.)

In sickly standing trees and felled logs. Larvae excavate long galleries, penetrating the heartwood. Pupation occurs in the wood, or in the bark if this is very thick. Capable of causing considerable damage to timber.

*Liopus nebulosus* L. (L. 5 to 8 mm.)

*Prionus coriarius* L. (L. 25 to 38 mm.)

*Rhagium inquisitor* F. (L. 15 to 19 mm.)

*Strangalia armata* Herbst. (L. 11 to 17 mm.)

The above species may occur in sickly trees or decaying timber, but economically are of little importance.

*Cerambyx cerdo* L. (L. 20 to 33 mm.)

*Cerambyx Scopolii* Laich. (L. 30 to 40 mm.)

These insects attack standing trees and the larvae cut large tunnels in sound wood. On the Continent they are particularly important and may cause serious damage to timber. They have been recorded from Great Britain, but were probably introduced in imported oak and do not breed in English timber.

(*d*) *Lymexylon beetles—Lymexylonidae.* This family of insects is now rarely met with in Great Britain, largely because of the scarcity of extensive areas of old oak forests. They are, however, of considerable importance in Europe and America, and injury caused by them to imported oak is frequently found (e.g. *Melittomma sericeum* Harr. in American oak). The beetles attack freshly felled oak logs, sometimes standing trees, and lay their eggs singly in cracks and crevices in the bark. The damage to the timber is caused by the larvae which, after boring for some distance between the bark and the wood, penetrate the sap and heartwood, cutting slender linear tunnels across the grain. Large quantities of wood-dust of a coarse fibrous nature are pushed to the surface of attacked logs. The presence of this dust, together with the absence of ambrosia fungi and the associated discoloration, distinguish the type of injury caused by Lymexylonid beetles from that produced by the pin-hole borers. The larvae of this group of insects are characteristic in appearance, being slender and elongate with three pairs of legs and a much enlarged and arched prothorax. A further notable feature is the presence of a special appendage on the last segment of the body. Methods of preventing the injury caused by these beetles again consist of rapid conversion and seasoning of felled timber. Two species of the family occur in Great Britain:

*Lymexylon navale* L. (L. 4½ to 10 mm.)

At one time very injurious in this country to oak used for the construction of ships.

*Hylecoetus dermestoides* L. (L. 6 to 15 mm.)

Found in oak but occurs in other hardwoods, and also in coniferous timbers.

II. *Lepidoptera* (Moths and Butterflies).

The type of defect caused by wood-boring caterpillars is characteristic, and consists of a few broad and long tunnels excavated in the growing tree. On

conversion, a number of boards may be rendered useless because of the presence of extensive tunnels. In Great Britain the species chiefly responsible is:

*Cossus cossus* L., the Goat moth.

The eggs of this insect are laid near the base of growing trees and the caterpillar bores extensively into the heartwood. The fully-grown larva measures 3 to 3½ inches in length and the tunnels which it cuts are correspondingly large. The grub is of a general yellowish-pink colour but is somewhat dark reddish on the back. An infested tree can be recognized by the presence of wood-shavings and chips pushed out from the tunnel near the base of the stem. The caterpillar has a characteristic odour which has been compared to that of a he-goat, and is frequently found in willows and poplars, but it occurs also in other hardwoods, including oak.

In American oak a similar type of defect is caused by the larva of the closely related Carpenter moth, *Prionoxystus robiniae* Peck.

INSECTS ATTACKING SEASONED TIMBER.

*Recently Seasoned Timber.*

(*a*) *Longhorn beetle—Cerambycidae.*

*Phymatodes testaceus* L. (L. 8 to 14 mm. Plate X, fig. 3)

Although most of the Longhorn beetles attack green or decayed and moist timber, the larvae of this species is frequently found under the bark or in the sapwood, occasionally in the heartwood, of dry or partly dry oak and other hardwoods, where it cuts its tunnels (Plate XII, fig. 2) and produces quantities of bore-dust. The larva (Plate XI, fig. 1) is a typical Longhorn grub, elongate, fleshy, yellowish-white, excavates when fully grown an oval-shaped tunnel about 3 to 6 cm. in the wood, and there pupates. The injury thus caused is not usually serious but may be found commonly. This insect is the Longhorn found most abundantly in hardwood timber-yards in this country.

(*b*) *Powder-post beetles—Lyctidae.* This group of insects is by far the most important of those attacking oak timber and is responsible for serious losses to a large variety of trades. These insects are commonly called Powder-post beetles from the manner in which their larvae reduce attacked timber to a fine flour-like powder (Plate XII, fig. 4). The adult beetles (Plate X, fig. 1) are small, somewhat flattened and elongate insects, varying in colour from reddish brown to black and averaging 4 mm. in length. They deposit their eggs within the pores of sapwood of oak and other hardwoods, and the larvae which emerge in due course tunnel in the sapwood only, feeding and growing during the spring and summer months. The full-grown larva (Plate XI, fig. 2) is a small, curved, white, wrinkled grub, 5 to 7 mm. in length, with three pairs of minute legs on the front part of its body. Infested timber can usually be detected by the presence of small piles of very fine wood-dust on the surface of, or beneath infested wood, but little sign of the attack may be apparent externally until beetles bore their way out some twelve months after they emerged, as larvae, from the eggs. For this reason, holes in timber caused by *Lyctus* are nearly always a sign that infestation is of a year or more's standing.

The *Lyctus* beetles cause serious losses to trades using the sapwood of oak or other susceptible hardwoods where stores of these are held in stock, either in the form of boards, planks, squares, or partly manufactured products laid aside in storage sheds prior to assembling into furniture or other articles. Thus, those primarily concerned include hardwood-timber merchants, furniture manufacturers, architects, builders, joiners, flooring and paving-block manufacturers, &c. The losses incurred are usually the outcome of the use of *Lyctus*-infested timber and of the necessity for replacing this with sound material, if and when infestation is discovered in the finished product.

Control measures consist of elimination of sapwood, regular inspection of stocks, segregation of infested material, or a heat sterilization treatment where kilns are available. It was suggested by Mer (8) that by ringing trees during the spring prior to felling in the following winter, timber could be obtained free from starch and would in consequence not be attacked by *Lyctus*. Confirmation of this theory has been obtained by Campbell (1), who has shown that the larvae of *Lyctus* feed upon the cell contents of the sapwood of oak, and by Wilson (10), who has carried the matter a step farther and has determined that the starch in these cells constitutes the food of the insect. Log-seasoning of oak, ash, walnut, and certain other hardwoods is advocated by Wilson (11) as a practical method of obtaining starch-free timber, immune from *Lyctus* attack. The economic importance of this group of insects and methods of preventing their increase and the damage they cause are discussed in detail in Forest Products Research publications (3, 4). The following are the species commonly found in English oak:

*Lyctus brunneus* Steph. (L. 3 to 5 mm. Plate X, fig. 1)
The most abundant species; a native of South America but now cosmopolitan.

*Lyctus linearis* Goez. (L. 2½ to 5 mm.)
Less common; a native of Europe.

In addition to the above, there are three species of *Lyctus* which are frequently found in this country in American oak, and one in Japanese oak. The habits of all the species of *Lyctus* are similar, and it is to be expected that all are able to attack English timber and may therefore become established in timber yards and stores throughout the country. The prevention of the spread of *Lyctus* beetles in hardwoods in Great Britain is the most serious insect problem which confronts the timber and allied trades at the present time. It has been suggested that legislation should be used to prevent the importation of *Lyctus* in imported timber. No action can, however, be taken in this direction, or to induce exporters overseas to take steps until a widespread and thorough clean-up campaign is put into operation in this country. One of the first methods that can be adopted to secure this end is for the merchant and user of home-grown oak to ensure that their stocks and premises are free, and are kept free, from the species of *Lyctus* which live in this country. Unless control measures are applied to prevent the ravages caused by *Lyctus*

powder-post beetles, the damage will increase and the home timber trade may be called upon to control not two, but at least six different species of this destructive insect.

(*c*) *Powder-post beetles—Bostrychidae.*

*Apate capucina* L. (L. 8 to 14 mm.)

This beetle occurs doubtfully in English oak but at times is found in oak imported from the Continent and may cause extensive damage. The nature of its injury is similar to that caused by the *Lyctus* beetles. The holes and tunnels are, however, larger, and therefore more easily detected. The adult beetle is conspicuous by reason of its orange-red wing covers, and black head and thorax.

*Old Timber.*

*Furniture beetles—Anobiidae.* These insects attack well-matured old timber and are the most frequent cause of 'worm' in timber and old furniture. They can infest both sap and heartwood and, although in general their rate of working and development is considerably slower than that of the powder-post beetles, they can cause extensive damage. As with most other wood-boring insects attacking oak, the injury is caused by the larva which tunnels its way through the timber, producing bore-dust, the texture of which is often a useful diagnostic character for the determination of the species present. Larvae of the furniture beetles are small, curved, yellowish-white grubs similar in shape to the larvae of the powder-post beetles. The fully-grown larvae of the Anobiid beetles are armed with small spinules on their backs which are absent in *Lyctus* larvae.

*The Death-watch beetle—Xestobium rufovillosum* De G. (L. 7 to 9 mm. Plate X, fig. 4.) The name 'death-watch' is derived from the tapping sound produced by the adults which is audible during April and May, the mating period of the insects. This beetle, the largest of the British Anobiids, is of a dark chocolate-brown colour, but is coated with patches of yellowish hairs which give the insect a variegated appearance. The exit holes made by this insect measure 3–4 mm. in diameter. Little information has yet been published upon the duration of the life-history of this beetle, but it is apparent from recent work (2) at Princes Risborough that this is dependent upon temperature conditions, the moisture content of the timber, and the presence or absence of decay due to fungal attack. The natural habitat of *Xestobium* is in dying or dead trunks and larger branches of oak, willow, hawthorn, and other hardwood trees, the damage in such positions being unimportant. When structural timbers are attacked (Plate X, fig. 3), however, they are frequently so weakened as to necessitate their removal and replacement. Oak is the timber most commonly attacked, both sap and heartwood. The insect may also occur in furniture of large dimensions, for example, in church pews and screens, but is rarely found in chairs or small articles. Recently seasoned timber is not attacked, but the beetle confines its attention to old timbers, and for this reason its ravages are usually associated with roofing or flooring timbers in ancient and historic

buildings. The workings of *Xestobium* can easily be distinguished from those of other furniture beetles by the nature of the wood-dust, which contains numerous large bun-shaped pellets characteristic of this insect.

In considering the treatment of a building in which the ravages of the death-watch beetle have been noticed, it is necessary to determine as far as possible whether or not the insect is still active. The progress of attack is slow and its presence does not always indicate serious decay. A summary (5) of control measures is given in Forest Products Research Leaflet No. 4, in which special attention is drawn to the importance of providing good ventilation, of avoiding access and accumulation of moisture, as through a leaking roof, and of excluding sapwood in timber used for all repairs, as valuable means of preventing attack.

*The Common Furniture Beetle—Anobium punctatum* De G. (L. 2½ to 4½ mm. Plate X, fig. 2.) This insect is considerably smaller than the death-watch beetle, is of a blackish-brown colour and lacks the variegated appearance of *Xestobium*. The exit holes made by the beetle are correspondingly smaller, measuring about 2 mm. in diameter, approximately the same size as those made by *Lyctus* beetles. The life-history of *Anobium* is shorter than that of the death-watch beetle and may occasionally be completed within one year. More frequently, however, it is prolonged to two or longer, according to the conditions in the timber. The wood-dust produced by the tunnelling of the larvae (Plate XI, fig. 3) can be distinguished from that of *Xestobium* by the absence of the bun-shaped pellets; the wood-dust in this species contains smaller particles which are oval or cylindrical in shape. This insect occurs commonly out of doors in the decayed parts of trees, and fence or gate posts. It is frequently found along with the death-watch beetle in structural timbers, but in oak its ravages are usually confined to the sapwood. In old furniture, the most familiar type of insect damage is caused by this insect which attacks both hardwoods and softwoods, and in this respect differs from the death-watch beetle which is rarely found in coniferous timber. Treatment (6) for control is similar to that required for *Xestobium*, but, since the insect occurs principally in small articles of furniture, it is more practicable to carry out careful and repeated treatments with insecticides. As in the case of other furniture beetles, the chief difficulty to be overcome is to secure, by surface application, adequate penetration of an insecticide. Provided the treatment is repeated over a period of 2 to 3 years, this method offers hope of success when the timber attacked is of small dimensions and easily handled.

*The Beech Furniture Borer—Ptilinus pectinicornis* L. (L. 3 to 6 mm.) This beetle is larger than the common furniture beetle and can be recognized by its cylindrical form, dark brown colour, and the feathered or pectinate antennae of the male. It is not so important as the preceding species and is found only occasionally in oak, preferring beech and sycamore. The bore-dust is quite distinct from that of the other furniture beetles, is flour-like in texture, and resembles that produced by the *Lyctus* Powder-post beetles. The insect attacks sap and heartwood but details of its life-history are not fully known.

INSECTS FOUND IN DECAYING OAK TIMBER.

As in any other timbers, there are numbers of insects which are to be found only in decayed and rotten wood permeated with fungi and in a very moist condition. Such insects are of little importance when considered in relation to the damage they cause to the timber, but economically are of value as scavengers. Mention has already been made of a number of Longhorn beetles found in the decayed portions of oak logs. The following list of insects is given because inquiries have been received at the Laboratory concerning the majority of these:

COLEOPTERA (Beetles).

Family *Oedemeridae*.

*Anoncodes* (*Nacerda*) *melanura* L. (L. 7 to 12 mm.)

The larva lives in old wood which is periodically submerged in water or in a permanently damp condition; common in timber structures on the sea-shore.

Family *Lucanidae*.

*Lucanus cervus* L., the Stag beetle. (L. 25 to 75 mm.)

*Dorcus parallelopipedus* L. (L. 18 to 20 mm.)

*Sinodendron cylindricum* L. (L. 12 to 16 mm.)

The larvae of the above live in rotten timber or stumps and roots of oak and other hardwoods.

Family *Cossonidae*, e.g.

*Pentarthrum huttoni* Woll.

*Rhyncolus lignarius* Marsh. (L. 3 to 3½ mm.)

Weevils living in rotten portions of bark and timber of hardwoods, occurring in pockets on standing trees or logs. The workings are very similar to those of *Anobium*.

There are innumerable other insects which cannot be mentioned specifically, living in similar situations, e.g. beetles of the families *Mordellidae*, *Melandryidae*, *Tenebrionidae*, *Elateridae*, *Staphylinidae*. In addition, the larvae of certain flies, for example representatives of the family *Cecidomyidae* occur in the fungus-attacked portions of oak timber, as also do numerous larvae of certain moths. No mention is made in this account of insects associated with oak timber of the groups of parasites and predators which prey upon the species mentioned.

ACKNOWLEDGEMENTS.

The writer is indebted to Mr. W. A. Robertson, Director of Forest Products Research, for permission to publish these notes, and to the Photography Section of the Laboratory for the preparation of the illustrations.

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## EXPLANATION OF PLATES

Plate X.

Fig. 1. Powder-post beetle, *Lyctus brunneus* L. × 10.
Fig. 2. Common Furniture beetle, *Anobium punctatum*, De G. × 10.
Fig. 3. Longhorn beetle, *Phymatodes testaceus* L. × 5.
Fig. 4. Death-watch beetle, *Xestobium rufovillosum* De G. × 10.

Plate XI.

Fig. 1. Larva of *Phymatodes testaceus* L. × 5.
Fig. 2. Larva of *Lyctus* sp.: note size of breathing pore (*A*) on eighth abdominal segment. × 10.
Fig. 3. Larva of *Anobium punctatum*: note rows of spines (*B*) on dorsal segments. × 10.

Plate XII. Types of Damage (natural size).

Fig. 1. Pin-hole borer, *Platypus cylindrus* F.: note absence of wood dust.
Fig. 2. Longhorn beetle, *Phymatodes testaceus* L.
Fig. 3. Death-watch beetle, *Xestobium rufovillosum* De G.
Fig. 4. *Lyctus* Powder-post beetle: note damage confined to sapwood.

PLATE X

PLATE XI

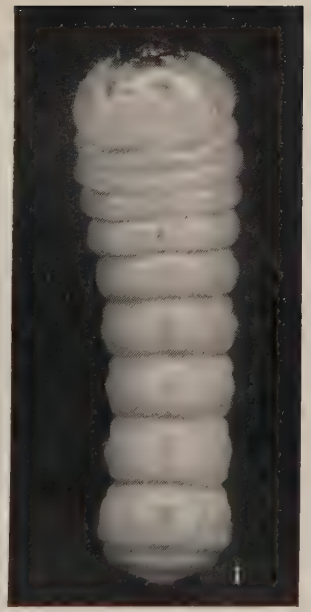

FIG. 1. Longhorn beetle.
*Phymatodes testaceus* L. (× 5)

FIG. 2. Powder-post beetle.
*Lyctus* sp. (× 10)

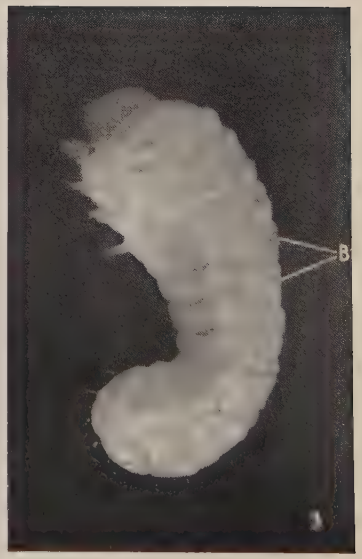


FIG. 3. Furniture beetle.
*Anobium punctatum* De G. (× 10)

*Fig. 2 reproduced by permission of the Controller of H.M. Stationery Office, from Forest Products Research Bulletin No. 16*

LARVAE OF WOOD BORERS

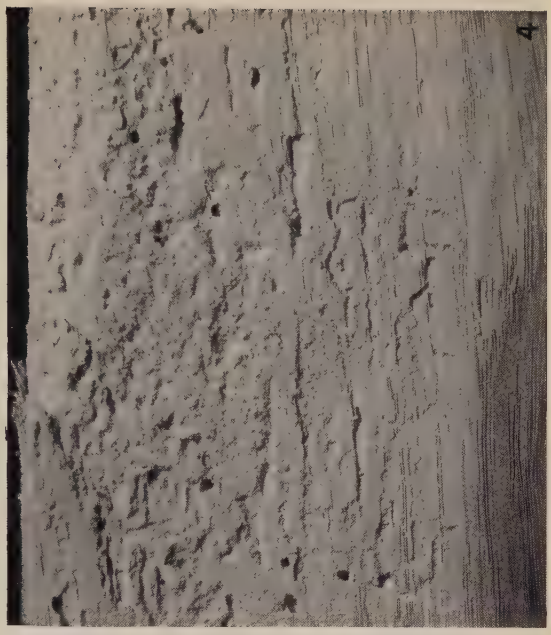

PLATE XII

## APPENDIX

*Classification of Defects caused by Insects in the Timber of English Oak*

| *Type of defect* | *Description* | *Insects responsible* | *Remarks* |
|---|---|---|---|
| Pin-holes (*a*) | Holes $\frac{1}{32}$ to $\frac{1}{12}$ in. in diameter. Wood-dust in tunnels absent. Tunnels usually darkly stained. In sap and heartwood. | Pin-hole borers (*Scolytidae* and *Platypodidae*) in sickly standing trees and green logs. | Damage to felled timber preventable. Wood dust on surface of attacked logs (dust fibrous in case of *Platypus*). |
| (*b*) | Holes about $\frac{1}{8}$ in. in diameter. Wood-dust in tunnels absent, or, if present, in tightly packed wads. Tunnels usually not darkly stained. In sap and heartwood. | Larvae of beetles of the family *Lymexylonidae*, in standing trees and green logs. | Damage to felled timber preventable. Now rarely found in English oak. Dust on surface of attacked logs, coarse and fibrous in texture. |
| Grub-holes (*a*) | Holes larger than $\frac{1}{4}$ in., oval and darkly stained. Dust in tunnels usually absent. In sap and heartwood. | Wood-boring caterpillars (Lepidoptera) in standing trees. | Damage not preventable. |
| (*b*) | Holes more than $\frac{1}{4}$ in. in diameter, oval but not stained. Dust usually present, tightly packed in tunnels. In sap and sometimes in heartwood. | Larvae of Longhorn beetles (*Cerambycidae*), usually attacking green timber or timber partly decayed by fungi. Occasionally larvae found in seasoned wood. | Damage to felled timber usually preventable. |
| Powder-post Damage | Holes $\frac{1}{16}$ in. in diameter, not stained. Dust abundant: fine, flour-like. In sapwood only. | Larvae of Powder-post beetles (*Lyctidae* and *Bostrychidae*) in partly and recently seasoned wood. | Damage preventable: insects capable of causing serious losses. |
| Furniture Beetle Damage. | Holes $\frac{1}{16}$ to $\frac{1}{8}$ in. in diameter, according to species. Not stained. Dust present, granular in texture except in the case of *Ptilinus pectinicornis*. In sap and heartwood. | Larvae of the Furniture beetles (*Anobiidae*) in well-matured old wood. | Damage preventable. |

In the above table mention is made only of the defects, caused by insects, likely to be found in felled timber or in timber in buildings and furniture. Bark beetles and other species which occur in decayed trees or logs are not included.

# A TEST FOR THE PRESENCE OF NATURAL PRESERVATIVE SUBSTANCES IN WOOD

BY ELIZABETH C. M. ERNEST

(Forest Products Research Laboratory)

THE durability of timbers in service depends very largely on the conditions under which they are used. There is also, however, a wide variation in their inherent natural resistance to fungal decay. The nature of the resistance which certain timbers show towards decay organisms has not yet been thoroughly investigated. Some timbers while immune to most wood-destroying fungi are susceptible to the attack of certain specialized forms.

While it is not to be expected that durability should, in every instance, be dependent on any one innate property, be it physical structure or chemical composition, it has, however, been established that certain of the more durable woods contain definite substances which prevent or check the growth of fungi. Such toxic substances have been looked for in the water-soluble extractives of the woods studied, by Sowder (5) and by Hawley, Fleck, and Richards (3), who worked with ten woods reputed to be durable, and by Anderson (1), who investigated the toxicity of water extracts of Western yellow pine (*Pinus ponderosa* Lawson) to *Lenzites saepiaria*. It is probable that there also occur in some resistant timbers, substances toxic to fungi, which are not soluble in cold or hot water. Migita (4) has shown that the highly durable wood of *Thujopsis dolabrata* S. et Z. contains a substance soluble in alcohol-benzene which is toxic to fungi. Such substances may become active when in contact with enzymes or other secretions from the fungus. Western red cedar (*Thuya plicata* D. Don) has been known for a long time as a remarkably durable wood; although the standing tree is sometimes attacked by specialized fungi, the felled timber is one of the few light softwoods which show a very high natural resistance to attack. The immunity of Western red cedar was shown by Sowder (5) to be due, at least in part, to the presence of some water soluble substance or substances.[1] This was demonstrated by extracting from sawdust, by a tedious and laborious technique, the materials soluble in cold and hot water, and adding these extracts to nutritive media, to give a range of concentrations of the 'poison'. These media were then inoculated with wood-destroying fungi in the usual way, and the subsequent rate of growth on the different concentrations of extract compared with growth on unpoisoned medium.

A more rapid means of determining the presence or absence in a timber of any natural preservative substance has given results which are notable for the ease with which they can be interpreted. The method cannot of course be

[1] Anderson and Sherrard (2) have isolated a highly unsaturated acid, which they term dehydroperillic acid, from Western red cedar, to which they ascribe the toxic action.

used to determine the natural durability of a timber in practice, which is dependent on its physical properties as well as upon its content of substances toxic to fungi. A small number of standard-size petri dishes is used. A glass slip is inserted to divide each lower dish into two approximately equal compartments, one of which is packed with suitably moistened sawdust from the air-seasoned heartwood of the given timber. The dishes and sawdust are sterilized by steaming for one hour on each of three successive days. Sterilized malt agar (about 10 cc.) is poured into the other compartment of each petri dish, under sterile conditions, and inoculated when cool with a known wood-destroying fungus. It was expected that any toxic substance moderately soluble in cold water would diffuse from the sawdust into the agar, where the two substrata are in contact below and at the sides of the loose glass slip, and that this would prevent or retard the growth of the inoculum. In the absence of any water-soluble or gaseous toxic substance, growth of the fungus should be of the usual radiating form over the agar. If the wood contains no toxic material the mycelium should spread in due time from the agar on to the sawdust and grow at more or less the same rate. Should the wood contain a toxic substance, which is, however, not soluble in the water of the agar gel, the hyphae may be expected to grow normally on the agar and then pile up against the glass slip but not spread on to the surface of the sawdust, or to spread over it at a considerably reduced rate.

The following woods, most of which are reputed to be resistant to fungal decay, have been subjected to this test:

Okan, *Cylicodiscus gabunensis* Harms.
Sequoia, *Sequoia sempervirens* Endl.
Bald Cypress, *Taxodium distichum* Rich.
Pitch pine, *Pinus palustris* Mill.
East African Pencil Cedar, *Juniperus procera* Hochst.
Jarrah, *Eucalyptus marginata* Sm.
Coachwood, *Ceratopetalum apetalum* D. Don.
Western red cedar, *Thuya plicata* D. Don.
Opepe, *Sarcocephalus esculentus* Afzel.
Cabbage bark, *Lonchocarpus Castilloi* Standl.
East African Camphor, *Ocotea usambarensis* Engl.
Wallaba, *Eperua falcata* Aubl.
Burma teak, *Tectona grandis* Linn. f.
Western Yellow pine, *Pinus ponderosa* Dougl.
Greenheart, *Ocotea rodioei* Mez.

The wood-destroying fungi used were:

*Lentinus lepideus* Fr.
*Coniophora cerebella* Pers.
*Polystictus versicolor* (Linn.) Fr.
*Fomes annosus* Fr.
*Lentinus tigrinus* (Bull.) Fr.

## TABLE I

| *Date of inoculation* | *Date of observation* | *Wood* | *Lentinus lepideus* | *Coniophora cerebella* | *Polystictus versicolor* | *Fomes annosus* | *Lentinus tigrinus* | *Merulius lacrymans* | *Polyporus fumosus* | *R. 1* | *Irpex tulipiferus* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 21.9.35. | 21.10.35. | *Okan* | Good growth over agar & sawdust | Good growth over agar & sawdust | Good growth over agar & sawdust | Good growth over agar & sawdust | | | | | |
| 8.10.35. | 21.10.35.<br>4.11.35. | *Sequoia* | No growth on sawdust<br>Fair growth on sawdust | Growth half over sawdust<br>Fair growth on sawdust | Some growth on sawdust | Growth over whole plate | No growth on sawdust<br>Fair growth on sawdust | No growth on sawdust<br>Fair growth on sawdust | No growth on sawdust<br>Fair growth on sawdust | Growth over whole plate | |
| 8.10.35. | 21.10.35.<br>4.11.35. | *Pitch pine* | No growth on sawdust<br>Fair growth | Very slight growth at edge of slip<br>Fair growth | Very slight growth at edge of slip<br>Fair growth | No growth on sawdust<br>Fair growth | | | | | |
| 8.10.35. | 21.10.35.<br>4.11.35. | *E.A. Pencil Cedar* | No growth on sawdust<br>„ „ | No growth on sawdust<br>Growth on sawdust checked | No growth on sawdust<br>Very slight growth. Checked | Growth at edge of slip only Sawdust covered | No growth on sawdust<br>Very slight growth. Checked | Growth on agar checked | No growth on sawdust<br>Checked | No growth on sawdust<br>Good growth | |
| 8.10.35. | 21.10.35.<br>4.11.35. | *Coach-wood* | Thick growth | Good growth over plate | Good growth over plate | Good growth over plate | Very slight growth<br>Good growth | Very slight growth<br>Good growth | Very slight growth<br>Good growth | Good growth | |
| 8.10.35. | 21.10.35. | *Jarrah* | Growth half over sawdust | Sawdust covered | Sawdust covered | Sawdust covered | Very slight growth | Slight growth | Good growth | Good growth | |
| 8.10.35. | 21.10.35. | *Bald Cypress* | Scarce growth on sawdust | Scarce growth on sawdust | Scarce growth on sawdust | Good growth over sawdust | No growth on sawdust | No growth on sawdust | ⅛ over sawdust | Good growth right over sawdust | |
| 29.10.35. | 2.12.35. | *Western red cedar* | Growth on agar away from sawdust | Growth on agar away from sawdust | Growth on agar away from sawdust | Growth on agar away from sawdust | Scarce growth | No growth, inoculum dead | Slight growth away from sawdust | | |

TABLE I (*continued*)

| *Date of inoculation* | *Date of observation* | *Wood* | *Lentinus lepideus* | *Coniophora cerebella* | *Polystictus versicolor* | *Fomes annosus* | *Lentinus tigrinus* | *Merulius lacrymans* | *Polyporus fumosus* | *R. 1* | *Irpex tulipiferus* |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 29.10.35. | 2.12.35.<br>3.1.6. | *Cabbage bark* | Growth only on agar<br>,, | Growth only on agar<br>,, | Growth only on agar<br>,, | Growth ⅔ over sawdust Covered | Growth only on agar<br>,, | Growth only on agar<br>,, | Growth only on agar<br>,, | Growth on whole plate | |
| 29.10.35. | 2.12.35. | *Opepe* | Growth half over wood | Growth half over wood | Growth over whole plate | Growth over whole plate | Growth over whole plate | Growth over whole plate | Growth over whole plate | Growth over whole plate | |
| 29.10.35. | 2.12.35.<br>3.1.6. | *E.A. Camphor* | Growth over agar only No further growth | Growth half over sawdust | Growth over agar only No further growth | Growth over agar only | Growth over agar only | | | Growth over plate | |
| 30.11.35. | 3.1.6. | *Wallaba* | On agar only | Over whole plate | Very scanty on wood | Over whole plate | | Slight check on agar nearest sawdust | | | Over whole plate |
| 30.11.35. | 3.1.6. | *Burma teak* | Very scanty on sawdust, along edges of slip only | Scanty growth on sawdust | No growth on sawdust | Thin growth over sawdust | | Unchecked on agar. No growth on sawdust | | | Very scanty poor growth, over all sawdust. |
| 30.11.35. | 3.1.6. | *Western yellow pine* | Hyphae piled up by slip | Growth over whole plate | Growth at edges of slip | No hyphae beyond slip | | Slight check of hyphae nearest sawdust | | | Thin growth on sawdust, better than on teak |
| 30.11.35. | 3.1.6. | *Green-heart* | Hyphae piled up by slip | (Contaminated) | No growth on sawdust | Growth over whole plate | | No growth on sawdust | | | Thin growth on sawdust |

*Merulius lacrymans* (Wulf.) Fr.
*Polyporus fumosus* (Pers.) Fr.
*Polyporus tulipiferus* (Schw.) Over.
Unknown fungus designated R. 1., isolated from decayed roots of apple.

The results are summarized briefly in Table I. A number of the woods appeared to possess no toxic properties whatever, under these conditions. On okan, coachwood, jarrah, and opepe, for example, all the fungi used in the test grew evenly over the agar and passed without any delay over the sawdust. Sequoia somewhat checked *Lentinus lepideus* and *Polystictus versicolor*. Pitch pine had a slight retarding effect on the growth of the four fungi with which it was tested. East African pencil cedar checked the growth of *Merulius lacrymans* on agar, and of *Lentinus lepideus*, *Coniophora cerebella*, *Polystictus versicolor*, and *Lentinus tigrinus* on the sawdust but not on the agar, and had no apparent effect on *Fomes annosus* or R. 1. Bald cypress did not retard *Merulius* on agar, and gave only a slight check to the growth on the test fungi on the sawdust. Greenheart and Burma teak and Cabbage bark effectually prevented the test fungi, except R. 1. and *Fomes annosus* from passing over the glass slip. East African camphor similarly checked the same test fungi and also *Fomes annosus*.

With Western red cedar the fungi behaved in a different manner. The inoculum of *Merulius lacrymans* was killed. The other mycelia grew extremely slowly, not in the customary radiating form, but in a more or less triangular form from the inoculum in a direction away from the sawdust.

Plate XIII (Figs. 1–8) shows the appearance of the Western red cedar plates 3 weeks after inoculation with (Fig. 1) *Lentinus lepideus*, (Fig. 2) *Coniophora cerebella*, (Fig. 3) *Polystictus versicolor*, (Fig. 4) *Fomes annosus*, (Fig. 5) *Lentinus lepideus*, (Fig. 6) *Merulius lacrymans*, (Fig. 7) *Polyporous fumosus*, and (Fig. 8) the as yet unidentified fungus R. 1., which has shown itself the first to spread over all the other woods so far subjected to this test. Cabbage bark with *Lentinus lepideus* (Fig. 9) shows the normal appearance of mycelium radiating from the inoculum. After a further 9 weeks, however, the mycelium had covered the agar but had not spread on to the sawdust. (Fig. 32) East African camphor, which resisted the attack of most of the other fungi of the test, was partly covered by R. 1. after 3 weeks. Wallaba and Western yellow pine had a similar effect on *Merulius lacrymans*, causing the mycelium to grow only in a direction away from the sawdust. Wallaba had little effect on *Coniophora cerebella*, *Fomes annosus*, or *Polyporus tulipiferus*, but prevented the spread of *Lentinus lepideus* and *Polystictus versicolor*. Western yellow pine retarded all the fungi except *Coniophora cerebella*.

The behaviour of the test fungi on agar in contact with Western red cedar sawdust was remarkable. It was therefore desired to study the growth of these fungi in different concentrations of the toxic substance. Fifty grammes of sawdust from air-dried heartwood was extracted in 1,000 c.c. hot water for 3 hours. Six hundred cubic centimetres filtrate was obtained. This was

added to malt agar in different quantities, to give 20, 10, 5 and 0 per cent. extract, 2 per cent. malt, and 2 per cent. agar.

The medium was sterilized by steaming for one hour on 3 successive days, plated, and inoculated. Plates were also made at the same time from extracted and unextracted sawdust in the manner just described, steamed in the same way and inoculated at the same time. The area in square centimetres covered by the mycelium of each fungus tested, after 9 days, is given in Table II.

TABLE II

| *Substratum* | *Lentinus lepideus* | *Merulius lacrymans* | *Fomes annosus* | *Polystictus versicolor* | *Coniophora cerebella* | *R.1.* |
|---|---|---|---|---|---|---|
| Malt agar in contact with sawdust, not extracted. | No growth | No growth | 4·6 | 2·7 | 5·2 | 2·3 |
| Malt agar in contact with sawdust, extracted. | No growth | No growth | 3·1 | 4·1 | No growth | 3·0 |
| Malt agar containing 20 per cent. extract from Western red cedar. | No growth | No growth | 10·6 | 5·8 | No growth | 8·6 |
| 10 per cent. | 8·7 | No growth | 17·6 | 12·7 | 1·6 | 14·6 |
| 5 per cent. | 12·9 | No growth | 18·8 | 17·9 | 3·2 | 18·9 |
| Control, 2 per cent. malt agar. | 23·1 | 8·5 | 33·4 | 18·7 | 18·2 | 15·7 |

It may be observed that the lowest concentration of the extract appears to have stimulated R. 1. to more rapid growth, and has very little effect on *Polystictus versicolor*, halved the growth of *Lentinus lepideus* and *Fomes annosus*, and reduced the spread of *Coniophora cerebella* to $\frac{1}{6}$th of the control.

These tests have served to indicate certain woods which may with advantage be studied further, by the more elaborate technique of extracting the hot and cold water soluble contents and possibly the alcohol and benzene soluble substances. The reactions between wood-destroying fungi and different preparations of such extracts may be expected to suggest further lines of investigation into the complex problems of the nature and mechanism of toxicity.

SUMMARY.

A new method is described, for a simple test for the presence of natural preservative substances in wood. Okan, sequoia, bald cypress, pitch pine, East African pencil cedar, jarrah, coachwood, Western red cedar, opepe, cabbage bark, East African camphor, wallaba, Burma teak, Western yellow pine, and greenheart have been tested. The fungi used were *Lentinus lepideus*, *Coniophora cerebella*, *Polystictus versicolor*, *Fomes annosus*, *Lentinus tigrinus*, *Merulius lacrymans*, *Polyporus fumosus*, *Polyporus tulipiferus*, and an unknown fungus designated R. 1.

Petri dishes are partitioned by a glass slip and one half filled with moistened sawdust and the other with nutritive agar. A transplant from a culture of a wood-destroying fungus is placed on the agar.

If the wood contains no toxic substance the fungus grows evenly over the surfaces of both agar and sawdust. A toxic substance soluble in cold water present in Western red cedar, diffuses into the agar and markedly reduces growth over the part of the agar surface near the sawdust. In a third group of woods, the fungi spread evenly over the agar, but some of them are unable to grow over the sawdust. It is concluded that a toxic substance, insoluble or sparingly soluble in cold water, is present.

ACKNOWLEDGEMENT.

Thanks are due to W. A. Robertson, Esq., Director of Forest Products Research, by whose kind permission this paper has been published.

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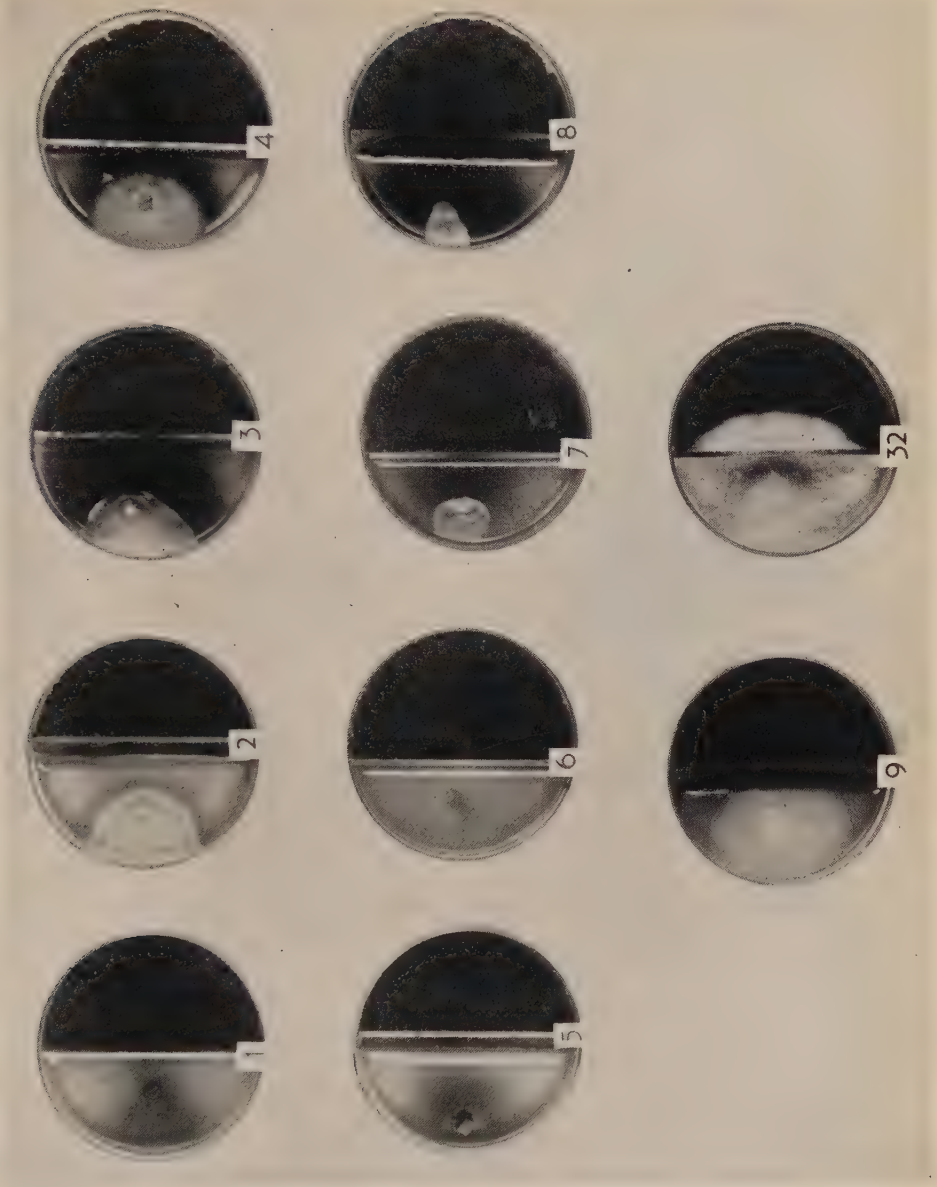


THE PRESENCE OF NATURAL PRESERVATIVES
A SIMPLE TEST

PLATE XIII

# A NOTE ON THE MANAGEMENT AND SILVICULTURE OF THE VOSGES FORESTS

BY M. R. K. JERRAM

## SITUATION AND CLIMATE.

THE forests to which this note refers lie for the most part on the slopes of the main range of the Vosges Mountains. This range lies in the north-east corner of France, running roughly north-east and south-west, and its water-shed separates France proper from the province of Alsace. The water-shed, which rises to a height of 4,400 feet and is broken up by no outstanding peaks, forms the boundary between two distinct climatic regions. The western region has a moist, equable climate with a heavy winter snow-fall. The eastern region has a typical continental climate with extremes of heat and cold, and, except near the summit of the range, is very dry, with little or no snow in winter. The rainfall, which is 80 inches per annum on the summit of the Vosges, decreases very rapidly as one descends the eastern slopes to the plain of the Rhine, until in the neighbourhood of Colmar it is only 19 inches per annum. In both regions storms do considerable damage at high altitudes. From the summit of the main range the eastern slope falls away abruptly to the plain of the Rhine, so that in this region the area of hill forests is comparatively small; towards the west, however, the range extends by subsidiary ridges with intervening valleys to a much greater distance, resulting in the area subject to the climatic conditions of the western region being considerably larger than that subject to those of the eastern region.

## TREE SPECIES.

The typical forest crops are as follows:

*High Elevations.* Beech with some Silver fir and occasionally spruce, artificially introduced.

*Middle Elevations.* Mixed Silver fir (60–80 per cent.) and beech (20–40 per cent.) with perhaps some spruce, artificially introduced. Also mixed Scots pine and Silver fir, particularly on sandstone soils in the eastern region.

*Low Elevations.* Coppice of oak, beech, Spanish chestnut, &c.; but most of these areas are being converted to high forest, largely by planting spruce and Silver fir.

## HISTORY OF PAST MANAGEMENT AND ITS RESULTS.

According to Huffel (*Économie forestière*, vol. iii, p. 400), up to about 1830 or 1840 all the forests, except those in the neighbourhood of towns and villages or on the hotter slopes, had been worked as Selection forest, and the general effect was that they contained a quantity of old timber mixed with patches of young wood with a deficiency of the middle age-classes. At that time—and, of course, for many years after—there was a great demand for products such

as fuel, charcoal, and bark, which are most readily obtained from coppice, and consequently the more accessible forests on the warmer slopes were for the most part worked on the Coppice or Coppice-with-Standards systems, with beech, oak, and other broad-leafed species. With the gradually decreasing demands for the products of coppice, the conversion of the latter forests to high forest was undertaken, generally by planting spruce or Scots pine, so that now coppice forests are of little importance except on some low-lying areas of the eastern region, where there is still a good demand for stakes for the vineyards producing the famous Alsatian wines. It may be noted that, as the spruce and Scots pine forests open out with advancing age, Silver fir almost invariably makes its appearance as a result of the seed being carried by wind from adjoining areas, and by the time maturity is reached the spruce will have been almost completely ousted by the last species, so that there will be none in the next rotation unless it is again artificially introduced. The spruce plantations, in fact, eventually revert to the mixed Silver fir and beech forests, which is the climax type for most sites. The Scots pine, if planted on localities where it is at home, that is the warm and dry slopes on sandstone soil, holds its own with the Silver fir. In the eastern region, at least, the Scots pine is by no means confined to old coppice areas and places where it has been introduced artificially in recent times. There are examples of magnificent mixed Scots pine and Silver fir forests where the former is probably indigenous (e.g. Freland, Ribeauville, and Wangenbourg).

With the idea of introducing greater regularity into the management and obtaining a more normal representation of the age-classes, the policy was gradually adopted of forming felling series to be worked on the periodic block system in nearly all those portions of each forest where considerations of protection did not prohibit it. Generally, a rotation of 144 years was adopted and divided into 4 periods of 36 years each. It was clearly the intention to make the allotment of compartments to these blocks permanent, and in many cases to make the blocks themselves self-contained. The attempt to regularize in this manner these very irregular forests naturally involved a great sacrifice of immature timber in the blocks first brought under regeneration and the accumulation of superannuated growing stock in the other blocks. An attempt was made to alleviate this situation by working over two blocks in the first period and preserving young growth (under 1 metre in girth) until the next rotation; but Huffel (p. 401) describes the results of the attempt to regularize these forests as deplorable. Up to the present time, however, considerable areas are still being worked under working plans which prescribe these fixed periodic blocks. In nearly all cases the method is breaking down, and it is likely to be replaced by the *quartier bleu* method (described later), except possibly in some localities in the eastern region where natural regeneration is supplemented by planting, more especially in the mixed Scots pine and Silver fir forests. Huffel's description of these forests (p. 403) is as follows: 'Our Silver fir woods are almost everywhere neither even-aged, to the extent that they are suitable for exploitation by crops, nor truly uneven-aged, that is, with age gradations

intermingled, so as to be suitable for exploitation by trees. This explains the introduction and rapid advance of the method of management by volume (the reference is to the *quartier bleu* method described in this note). It has the great advantage of imposing no particular cultural technique in the woods. Their present condition may be maintained, whether it is of the selection type, semi-selection type, or even-aged.'

Again, page 409: 'He who marks a felling will find in the same compartment, here, trees of all ages up to the exploitable size so intermixed that the operation assumes the character of a true selection feeling providing timber of various dimensions; there, an old open high forest standing over complete regeneration in which the operation will be of the nature of a secondary felling producing large timber; elsewhere he will be marking in a regular pole crop of beech, Scots pine, or spruce, growing on the site of an old windfall clearing where a thinning producing small wood will be carried out. In other words, one and the same *coupe* will produce at one and the same time both final and intermediate yields.'

As regards the forests which have been worked continuously on the Selection System, the results again have generally been unsatisfactory from the point of view of the production of the normal forest. The main reason for this has undoubtedly been the cutting of less than the true yield, as a result of over-caution in estimating, accentuated, in the case of the communal forests, by the custom of setting aside part of the calculated yield as a reserve against contingencies. In a selection forest the retention of over-mature trees not only results in loss of increment, but also interferes with the growth of the younger age-classes. After a time the forest will lose its irregular character and tend to become one of large trees standing over a thin and suppressed advanced growth. When the old trees are at length removed the remaining crop will, from the economic point of view, be a young, even-aged one. It is a characteristic of most of the selection forests in the Vosges that the middle age-classes are deficient and that they consist largely of even-aged patches of young and old woods. Storm damage accentuates the situation, both directly by the creation of large exposed surfaces, which may have to be planted up, and indirectly by delaying regeneration fellings in other parts of the forest until the windfalls have been dealt with.

## PRESENT MANAGEMENT.

The French unit for the calculation of the yield is a *Série*, which, except as stated below, is identical with our Felling Series, i.e. a management unit in which the object is to maintain or create a normal representation of age-classes. The idea of collecting a number of series, worked in the same manner, into a Working Circle, is foreign to French management. The term *Série*, however, may also be applied to a *reboisement*, an artistic or protection area in which there is no intention of establishing a normal representation of age-classes; in such cases it is equivalent to a Working Circle. The area of a series in the Vosges is anything from 200 to 800 hectares (say 500 to 2,000 acres).

A forest under one ownership—state or communal—may stretch from the summit of the mountain range down to the valleys, and may consequently occupy several climatic and topographical regions. At the highest elevations growth is slow, regeneration difficult, and the danger from wind great: consequently protection is the primary consideration, and one or more felling series may be constituted where light selection fellings only are carried out, or perhaps improvement fellings (*coupes d'amélioration*) designed to carry over an immature forest into a selection condition. Below this protection zone lie the forests where the objects of management are mainly commercial. Here, one of several methods of management may be practised, such as Selection, Periodic Blocks, or the Floating Regeneration Area (*quartier bleu*). The objections to the selection method have already been noted and the tendency is to replace it where possible by the *quartier bleu* method; but there are localities where danger from wind probably makes the change undesirable. At these mean elevations several series worked under different methods of management may therefore be constituted. Again, at lower elevations may be found coppice series, series under conversion from coppice to high forest, or areas of old rough pasture, no longer required to serve as such, which are being reafforested and are at present allotted to no series.

The following is a list and description of the different methods of management in force:

| *Basis of Management* | *Calculation of Possibility* |
|---|---|
| A. Fixed permanent periodic blocks (*affectations permanentes*). | By an inventory of the volume standing on the current regeneration block with or without an allowance for increment. |
| $A_1$. ditto | 1883 method or modifications thereof with or without *précomptage général* (inclusion of thinnings and windfalls in the possibility).[1] |
| B. Single block (*affectation unique*). | As A. |
| C. Floating regeneration area (*quartier bleu*). | 1883 method. |
| D. Selection by area (*jardinage par contenance*). | None made. |
| $D_1$. Selection. | 1883 method. One calculation for the whole series. |
| $D_2$. Selection. | 1883 method. Separate calculations for each cutting section. |

*A.* Many of the working plans prescribe fixed permanent periodic blocks, i.e. there is a parallel division of the rotation into periods, and of the series into blocks, one of the latter being allotted permanently to each period and numbered accordingly. Most commonly the rotation is 144 years, with 4 periods of 36 years each. Occasionally the periods are not equal. Everywhere the method is breaking down for the usual reason, namely, that the forester has not succeeded in coercing nature to regenerate a fixed area in a fixed time. The breakdown is less marked in the eastern region where natural regeneration is supplemented to a very considerable extent by planting and sowing. In

[1] Vide *Forest Management*, p. 55, by M. R. K. Jerram.

most places this method of management seems purely nominal, and when the working plans are revised it is anticipated that it will be dropped, though it may be retained in places where the soil is suited for Scots pine.

$A_1$. This method is included as it is actually prescribed in at least one forest (Val d'Ajol); but it represents an impossible combination, namely: abnormal forest, fixed P.B.'s, possibility calculated from the volume of the whole series. It expresses a tacit admission that management is not really by fixed P.B.'s.

*B*. The difference between this and *A* is that only the current regeneration block is constituted. The area (or reduced area) of the single block remains a fixed proportion of the whole series, i.e. it $= \frac{P \times S}{R}$, where $R$ = rotation, $S$ = total area, and $P$ = number of years in the period. The theory that the same compartments must always be regenerated in the same period in each rotation is abandoned, the position being reconsidered at the end of each period. Sometimes, however, the compartments which will be regenerated in the succeeding period are provisionally allotted. This is done in recognition of the fact that the thinnings and improvement fellings required in woods approaching maturity may differ somewhat in character from those required in young woods.

*C*. The compartments are allotted at each revision of the working plan to one of two blocks, the regeneration block (*quartier bleu*) or the thinning block (*quartier blanc*). The *quartier bleu* will be more than one quarter and may be as much as two-thirds of the total area; in any case it will be no fixed proportion of the area and no time will be laid down for completing its regeneration, as in the single block method. Occasionally a third block (*quartier jaune*) is established, for the same reason as the second block in the previous method, to which compartments, which are expected to be ready for regeneration at the next working-plan revision, are allotted; but this is rare. In the thinning block the thinnings are prescribed by area, the thinning cycle being a submultiple of the nominal rotation. The procedure followed in obtaining the annual yield is known as *précomptage général*; the thinnings and improvement fellings in the area prescribed are first marked; add to the volume thus obtained (only trees 20 cm. and over in girth) the volume of windfalls, and deduct this total from the calculated possibility. The balance is then marked in regeneration fellings in the prearranged compartments of the regeneration area. Generally, the compartments allotted to the *quartier bleu* will contain some woods in which thinnings are required, consequently these will be marked each year in compartments previously allotted to the year before any regeneration fellings are marked.

The formula for calculating the annual yield under the 1883 method is as follows:

$$\text{Annual yield} = \underbrace{\left\{\frac{V_1}{\frac{r}{3}} + \frac{V_1 \times t_1}{2}\right\}}_{\text{Large wood}} + \underbrace{\left\{\frac{1}{n}(V_2 \times t_2)\right\}}_{\text{Medium wood}}$$

$V_1$ = volume of large wood
$V_2$ = „ „ medium wood
where $t_1$ = increment per unit p.a. large wood
$t_2$ „ „ „ medium wood
$r$ = rotation, or rather mean age at which it is estimated mature trees will be felled
and $n$ is a factor varying according to circumstances.

$V_1$ and $V_2$ are obtained by a complete inventory of the series in 5 cm. diameter classes. $V_2$ is the volume of trees 20–40 cm. in diameter and $V_1$ the volume of trees over 40 cm. Nominally a tree of 60 cm. in diameter is mature and trees over that size represent surplus growing stock. Only rarely, however, is surplus growing stock separated from large wood. In applying the formula, consideration is paid to the difference between the actual and normal representation of age classes, at least in so far as this is indicated by the proportions of large and medium wood. It is considered that these proportions should be as 5 : 3 (derived from a geometrical representation of the growing stock with a division of the rotation into 3 parts), and that the actual quantities per hectare should be 200 and 120 cubic metres respectively. At one time the 5 cm. diameter classes were redistributed between the Large and Medium wood so as to make the proportions normal. Thus if medium wood were in deficit, it would be increased by transferring to it some of the lowest diameter classes of large wood, resulting in a reduction in the yield given by the formula, and vice versa. A little consideration will show that such transfers are very likely to defeat their object, and modern practice relies more usually on varying the values of the coefficients '$n$' and '$t$' in accordance with the manager's knowledge of the forest, in order to build up a more normal growing stock.

The explanation of the formula is as follows:

$\frac{V_1}{\frac{r}{3}}$ { The existing large wood will be removed in the period in which it will be replaced by medium wood, that is, in one-third of the rotation.

$+\frac{V_1 \times t_1}{2}$ { The annual increment of half the existing large wood will also be cut.

$+\frac{1}{n}(V_2 \times t_2)$ { That portion of the increment of the medium wood not required to replace large wood will also be cut in thinnings.

For approximately normal forests, the following figures are considered applicable:

$$t_1 = 0{\cdot}01,\ t_2 = 0{\cdot}03,\ n = 3.$$

*D*. Selection by area. The rotation and felling cycle, usually 10 years, are fixed and the former divided by the latter gives the number of cutting sections (or, in some forests, Compartments) into which the series is divided. A cutting section (*coupon*) is marked over each year in its proper sequence. No possibility is calculated. This method gives the silviculturist a free hand and is particularly suited to the protection forests.

$D_1$. Selection by volume. Rotation, felling cycle, and cutting sections are

prescribed as above and the annual yield, by the 1883 method, calculated for the whole series. Since the yield is fixed by volume, accidents, such as windfalls, in one cutting section may prevent fellings being carried out in another cutting section in the prescribed year, so that in practice the felling plan often merely indicates the sequence of felling and not the actual year of felling in each cutting section. Heavy damage by windfall in one cutting section may therefore have an injurious effect from the silvicultural point of view on another cutting section.

$D_2$. As $D_1$, but the yield is calculated for each cutting section separately. In this case each cutting section is marked in the prescribed year regardless of what is happening in other sections, so that the disadvantage of imposing a fixed volume possibility on such a purely silvicultural method as Selection is mitigated. An example of this method is seen in Remiremont Communal forest.

The rotations most usually in force in the Vosges for high forest are 150, 144, and 120 years. The thinning cycle is a submultiple of the rotation, being either 10 or 12 years.

## SILVICULTURE.

The silvicultural systems practised in the forests managed under the periodic block method is the 'Uniform System'. The technique, however, differs considerably from that practised in forests considered as typical of this system. This is due mainly to the fact that the principal species, the Silver fir and beech, are both shade-bearers, the former particularly so. Silver fir advance growth appears as soon as the canopy is opened at all, and care has to be taken in making the thinnings to avoid obtaining this advance growth prematurely in large quantities. In any case, in localities suited for the Silver fir, advance growth is invariably present before the regeneration fellings commence, so that the first operation under the Uniform System, the seeding felling, is seldom required. The first operation will usually be in the nature of a secondary felling to open out the crop sufficiently to enable beech regeneration to take place. Further fellings, two or three in number, will be carried out at rather long intervals (9 years is a usual period between them) and the regeneration in any one place may be completed in anything from 20 to 40 years, 36 years being the usually accepted length for a regeneration period in the mixed Silver fir and beech forests. But if there is insufficient Silver fir regeneration on the ground when the first felling is made, then the cover must be opened out with great caution, as the Silver fir will not regenerate satisfactorily in open spaces, and the object is usually to obtain 70 to 80 per cent. of this species. *It may be taken as an axiom that fellings must follow and not precede the appearance of Silver fir regeneration.*

In the mixed Silver fir and Scots pine forests in the eastern region the regeneration periods are shorter and the fellings are carried out much more rapidly. There is here no desire to maintain a high proportion of Silver fir. The advance growth of this species, which is already present on the ground

when the regeneration fellings are commenced, is generally sufficient, and a rapid opening out of the cover is necessary for the production of Scots pine regeneration. A marked feature of these forests is the number of places in which the final fellings are executed by the wind, and natural regeneration has to be supplemented by planting on a considerable scale. The final results are, however, excellent, the mixed Silver fir and Scots pine forests being of magnificent quality.

In the forests worked under the Selection system with a volume possibility calculated by the 1883 method, the imposition of a volume control often seriously interferes with the silvicultural operations required. Frequently the whole possibility is obtained in windfalls and improvement fellings before the selection fellings proper for the year have been commenced. There is a tendency, therefore, for old trees to be left too long with a bad effect both on regeneration and increment. A common defect in the selection forests is a deficiency in the middle age-classes.

It is not easy to find, under the British system of classification, a name for the silvicultural system, or systems, practised in the forests subject to the floating regeneration area method of management. The local French officers almost invariably apply the term *futaie régulière*, i.e. uniform, to the system practised. It is obvious that, where the regeneration area may extend to two-thirds of the total, the difference in the ages of the trees or crops in this area will be very great, amounting to a similar proportion of the rotation, and these age limits may be present in any individual compartment. This does not, of course, necessarily prohibit the silvicultural technique followed in any place from being uniform. The basis of the French terminology is, quite logically, the kind of crop which they eventually obtain (or, more correctly, hope to obtain) by their method of making the regeneration fellings and they seem to regard the question rather from the point of view of small silvicultural units than from that of the regeneration block as a whole or that of a compartment, representing the smallest management unit. Regarded from this point of view there are only two kinds of crop:

(*a*) A crop with trees of even height and closed canopy at maturity.

(*b*) A crop with trees of uneven height and open canopy throughout its life.

Provided their method of making the regeneration fellings is intended to obtain the former the local officers refer to the system as *futaie régulière*. If the intention is to produce a crop of uneven open canopy in which only individual trees will reach maturity at any time, then the system is referred to as *futaie jardinée* (selection). The crops within a regeneration area, as a result of frequent changes in the method of management, generally present such variations in character that, even accepting their own basis of classification, the classification of the silvicultural system as uniform hardly seems satisfactory. Actually these operations may be selection in one place and uniform at a little distance in the same compartment, suggesting that the system might be described as combined (Troup's *Silvicultural Systems*, p. 172). Giving, however, a somewhat more general interpretation to the term 'Irregular Shelter-

wood System' than is given by Troup (p. 73), I think that this is the best term to apply and I should describe the silviculture as 'Irregular shelterwood with a tendency towards local uniformity'. In some places the operations suggest the particular form of irregular shelterwood system known as *Baden Femelschlag* (Troup, p. 76). It must always be remembered, however, that the French deliberately refrain from prescribing any particular silvicultural technique in the forests worked under the *quartier bleu* method of management in this locality.

Excepting in those forests in which the Selection System has never been departed from, there have been so many changes in the method of management, from selection to periodic blocks and back again, that the forest crop seldom truly reflects the silvicultural system now in force, and it is often difficult to deduce the latter from observation of the former.

The impression conveyed after seeing a large number of different forests and discussing them with the local forest officers is that, although the silvicultural technique practised has almost everywhere been very successful in obtaining regeneration and developing fine woods, nevertheless management has not yet succeeded in deciding on the best combination of silvicultural system and yield regulation for the production of the highest sustained yield.

# DESTRUCTIVE FAIRY RINGS, ASSOCIATED WITH *PAXILLUS GIGANTEUS*, IN YOUNG PINE PLANTATIONS

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IN recent years a number of exceptionally interesting fungal fairy rings in young Scots pine plantations have been found. With one exception, which is at Heggiesmuir in Fife, they are in Thetford Chase, a Forestry Commission area on the borders of Norfolk and Suffolk. In this area fifteen rings have been recorded. As these rings, in the limited area which they cover, can do a good deal of damage, it was considered worth while to publish this note, in the hope that the author may receive further information on their occurrence or absence in other districts.

The general construction of the rings is shown in Fig. 1. In the centre we have a core of healthy trees (Fig. 4). Then comes a zone of dead ones; on the inner side of this zone many of the trees are missing and those that remain are definitely smaller than the present size of the trees (Fig. 5). Outside the zone of dead trees there is one where most of the trees are unhealthy and many

HEALTHY.
SMALL DEAD TREES, MANY MISSING.
LARGER DEAD TREES.
RING OF FUNGI IN AUTUMN.
UNHEALTHY AND DYING TREES.
HEALTHY TREES, THE REMAINDER OF THE PLANTATION.

FIG. 1. Section and plan to illustrate the general arrangement of the rings.

of them dying; in general the trees on the inner side of this zone tend to be in worse health than those on the outside. Finally, outside this again we have the healthy trees which form the bulk of the plantation in which the ring is situated. It must be understood that this is a diagrammatic description of a ring. In actual fact the whole ring may be very irregular, and parts of it may be missing, but in many of the rings all the stages listed above can be clearly seen and in most of them these stages can be found, once it is known that they exist.

The simplest explanation of this phenomenon seems to be that a fungus is spreading out concentrically, killing the pines as it goes. The healthy trees in the centre indicate that the pines were planted after the fungus had started, and that it had already passed over this central area. The small dead trees, many of which are now missing, were killed soon after planting, the larger dead trees outside them are the more recent deaths, and the unhealthy trees represent the present activities of the fungus. This explanation is supported by the facts that a ring of fructifications occurs each autumn, usually somewhere near the inside of the zone of unhealthy trees, and that digging under this ring discloses a veritable mat of mycelium in the soil. In the case of the Thetford rings the fungus invariably occurring is *Paxillus giganteus* (Sow.) Fr. The fungus occurring at the Heggiesmuir ring was identified, from a specimen in poor condition, as *Paxillus extenuatus* Fr., but it is possible that this ring is also in reality associated with *P. giganteus*.

No attempt will be made here to review the literature on fairy-ring formation by fungi, or to discuss in detail the theories of fairy-ring development; for this, reference should be made to Shantz and Piemeisel (4) and Bayliss Elliott (2). It is generally agreed that the fungus grows only in an outward direction because it has used all the suitable nutriment in the area over which it has passed. This is supported by the fact that two rings meeting do not cross, but die out at the point of contact, so that one large irregular ring is formed. In many rings in pastures the grass is first stimulated, then killed, and then the grass which grows on the dead area when the fungus has passed on is again stimulated. It is agreed that the stimulation on the outside of the ring is due to the utilization by the grass of extra available nutriment provided by the action of the fungus on the humus. The stimulation of the vegetation on the inside of the ring is believed to be due also to the utilization by the grass of the products of decomposition of the dead mycelium. But the reason for the death of the grass between these two zones is a matter on which there is no agreement. Shantz and Piemeisel (4) state that it is due to drought following on the inability of water to penetrate the thick mat of mycelium which cuts off the roots of the grasses from the water available below. Bayliss Elliott (2), on the other hand, states that the grass dies owing to the toxic effect of the fungus on its roots. No accusation of true parasitism seems to have been made against these ring-forming fungi. *Paxillus giganteus*, under the name *Clitocybe gigantea*, has been described by Bayliss (1) and Bayliss Elliott (2) as damaging grass, and was assumed to be toxic to the grass roots. According to Rea (3), it is not uncommon in this country, occurring on pastures and heaths, and rarely in woods. The author has noted it forming large rings in a pasture near Aviemore, Inverness-shire (Fig. 2). The effect of the fungus on the pines has several well-marked characteristics. The older needles are shed, and the most recently formed shoots are inclined to be short, and the needles on them unusually close together, giving a tufted appearance to the tree (Fig. 3). Later, individual branches die back until finally the tree is wholly dead. Sometimes, possibly owing to the effect of drought, death takes place more rapidly,

and there is no time for the 'tufted growth' stage to develop before dying back starts. This damage begins before the main mat of mycelium has reached the trees, and, as regards the soil, the only obvious difference from an unaffected area is the presence of a good deal of mycelium round the roots; but nothing in the nature of a mycelial mat is found in most of the zone occupied by the dying trees. The mycelial mat is to be found only on the inner edge of this zone and in the outer part of the zone of dead trees, in fact underneath the ring of fructifications. Since damage commences and in many cases death takes place before the mycelial mat has reached the tree the drought theory of Shantz and Piemeisel (4) can hardly apply here, and it seems almost certain that we are concerned either with a toxic effect of the fungus on the tree, or with actual parasitism. No further evidence on this point is available.

The rings vary in diameter from 24 to 100 yards, but, as has already been stated, they are often very irregular in outline. In some instances they appear to have died out in places and are no longer continuous, and in others the rate of growth has been so variable that one part of a ring may be found growing back towards another part. But more important than the size of the rings is the rate at which they are spreading. Typical figures for this are given below:

Heggiesmuir Ring: 5 feet per year over a period of 9 years.
Thetford Rings: 1 to 5 feet per year over a period of 7 years.
1 to 3½ feet per year over a period of 7 years.
2½ feet per year over a period of 7 years.

These figures were procured by measuring the width of the ring from the inside of the dead to the outside of the unhealthy zone, and dividing by the number of years since the pines were planted. The figure is therefore an average, and actually the advance may have been faster in some years and slower in others. Where two rates are given these refer to the maximum and minimum measurements for a variable ring. Only the Heggiesmuir ring has been subject to constant observation over a period of years, and for this it is possible to give the number of deaths in each year. The trees were planted in the winter of 1923–4.

| | | |
|---|---|---|
| Deaths during | 1924 | 14 |
| ,, ,, | 1925 | 7 |
| ,, ,, | 1926 | 33 |
| ,, ,, | 1927 | 25 |
| ,, ,, | 1928 | 25 |
| ,, ,, | 1929 | 26 |
| ,, ,, | 1930 | 28 |
| ,, ,, | 1931 and 1932 | 46 |

It will be noted that the number of deaths did not, as might have been expected, increase with the size of the ring. This was due, in the main, to the fact that after 1927 the ring started to die out on one side.

In all cases the rings are on sandy soil, but at Thetford chalk occurs in most instances only a few feet down, and where there has been trenching to stop the spread of the fungus (Fig. 5) the chalk from the trench now outlines the ring. Previous to planting all the areas were heathland—in the case of Heggies-

muir grass heath, and in most instances at Thetford grass heath with a good deal of bracken. In the Thetford ring, areas of dead and dying grass often from 3 to 10 feet square are found from January to April and even later. They occur in the same part of the rings as the fructifications, i.e. over the mycelial mat. These dead patches are not so marked when the predominating grass is *Festuca*, but are much commoner in the better grass types such as *Holcus*, *Anthoxanthum*, *Poa*, and *Dactylis*. They are presumably of the same nature as those described in papers on fairy rings in pastures. Also the amount of bracken in the more recently affected parts of the ring was definitely less than in the plantation outside, and there seems little doubt that some of the bracken perished with the pines and grass. Many of the Thetford rings lie beside strips of scrub hardwood, but in nearly every case the original centre of the ring was outside the wood, and it is difficult to see in what way the woodland could have assisted in starting the rings. In the absence of further information on this point, it must be assumed that the fact that so many of the Thetford rings are in such situations is merely a coincidence.

Part of the Heggiesmuir ring was trenched round in 1932, and so far this has proved successful in stopping the spread of the fungus. Most of the Thetford rings have now been treated in this manner with trenches varying in depth from 2 to 4 feet according to the nature of the soil, but in most cases going down to the chalk. It is too early yet to form any conclusion on the effect of these in stopping the spread of the fungus.

In conclusion the author would like to convey his thanks to the Forestry Commission for permission to publish the data collected on these rings, to Dr. M. L. Anderson and Mr. J. A. B. Macdonald for the figures relating to the Heggiesmuir ring, and to Mr. Nimmo, who supplied some of the information on the Thetford rings and took two of the photographs.

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(1) Bayliss, J. S.: 'Observations on *Marasmius oreades* and *Clytocybe* (*Paxillus*) *giganteus* as Parasitic Fungi.' *Jour. Econ. Biol.* vi, 1911, pp. 111–32.

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(3) Rea, C.: *British Basidiomycetes.* Cambridge, 1922.

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## DESCRIPTION OF PLATE XIV

Fig. 2. *Paxillus giganteus* forming a ring in rough pasture at Aviemore, Inverness-shire. The handle of the knife lying across the fructification in the left foreground is about 5 inches long. Photographed August 1934.

Fig. 3. Pine in the early stages of the disease. The older needles have been shed, and the last year's shoots are inclined to be short, and the needles on them close together, giving a tufted appearance (compare with healthy pine on the left). The shoots *AA* are just starting to die. Photographed February 1936.

Fig. 4. A moderate-sized ring at Harling, near Thetford. This has been trenched round, and

the chalk subsoil thrown from the trench marks the outer edge of the ring. In the centre of the photograph the unaffected trees in the middle of the ring are seen. Photographed November 1935.

Fig. 5. Part of the outer zones of a large ring at West Tofts, near Thetford. The laths mark the outer edge of the ring, and the crosses the remains of fructifications of *Paxillus giganteus*. In the left foreground is that part of the zone where the dead trees are small and many missing. Photographed November 1935.

PLATE XIV

# SPRAYING AGAINST *MERIA LARICIS*, THE LEAF CAST DISEASE OF LARCH

BY T. R. PEACE

(Imperial Forestry Institute, Oxford)

IN 1933, when a description of this disease of European larch in the British Isles was published (1), spraying experiments were still in progress and the measures advised were admittedly provisional. The most recent experiments to be described were those carried out in 1932, and since then three further years' results have been obtained, i.e. 1933–5. Since such experiments have now been discontinued, the time is ripe to make such alterations and additions to the original recommendations as have been suggested by the work of the past three years. No details of the disease, the species attacked, and so on, are given here. For this reference should be made to the earlier paper (1).

In 1933 and 1935 a good deal of difficulty was experienced owing to the fact that in neither year was the disease generally severe. In 1933 experiments were carried out in four nurseries, but had to be abandoned in two of them owing to lack of infection on the controls. At Rhinefield Nursery in the New Forest a certain amount of information was gathered on the maximum interval permissible between sprayings. Amberene (1½ per cent.) applied weekly gave a particularly striking control of the disease, but in practice such frequent applications would be impossible both on account of time and cost. Amberene of the same strength applied fortnightly or every three weeks also gave quite good control, but monthly sprayings were not satisfactory. In this same nursery spraying with various strong fungicidal solutions at the beginning of March proved to be of no value unless followed by further sprayings later in the season. At Nagshead, in the Forest of Dean, where various substances were tried, the following treatments gave very satisfactory control:

5 per cent. Amberene in early March followed by 1½ per cent. Amberene fortnightly.
1½ per cent. Amberene fortnightly.
2 per cent. Amberene fortnightly.
1 per cent. Lime sulphur fortnightly.
1 per cent. Sulsol fortnightly.

Less successful, but still controlling the disease to some extent, were:

1 per cent. Amberene fortnightly.
0·7 per cent. Liver of sulphur fortnightly.
1 per cent. Precipitated sulphur+0·2 per cent. caseinate spreader fortnightly.

One of the unsuccessful substances tried was a sulphur-resin preparation, which caused severe scorching and entirely failed to control the disease. With the exception of the first treatment listed above, spraying was started at the beginning of April.

In 1934 normal sprayings were carried out at Altonside Nursery, Moray-

shire, using 5 per cent. Amberene at the beginning of March, followed by 1½ per cent. Amberene at the beginning of April and thereafter fortnightly. Control beds were left unsprayed. This treatment gave fairly good control of the disease, though there was an unusually high percentage of very slightly infected plants in the sprayed beds; and the effect of the spraying was apparent only in the considerable lowering of the number of slightly infected plants, and in the absence of moderately and severely infected ones.

In 1935 an experiment primarily designed to test Sulsol at lower concentrations than those previously used was carried out at Newton Nursery, Morayshire. The fortnightly sprayings were started at the beginning of April. Of these 1 per cent. Sulsol, and 0·3 per cent. Sulsol plus 0·05 per cent. special wetting compound were both extremely successful, especially the latter. Treatment with 1½ per cent. Amberene was not very successful, being scarcely better than the unsprayed control beds.

On the basis of these experiments and those described in the previous paper (1) the following spraying recommendations can now be made. Spraying should commence at the end of February or the beginning of March, a second spraying should be given at the end of March or the beginning of April, to be followed by further sprayings at intervals of a fortnight or three weeks. The intervals between these should certainly not exceed three weeks, and the shorter interval of a fortnight is more desirable. Should settled dry weather set in, they may be discontinued as long as it lasts. In any case spraying should cease after the end of July, as defoliation after that date is unlikely to do much damage, and, if the disease is well in check at that time, a serious attack in the latter part of the season is unlikely. The following sprays can be used:

Amberene (1½ per cent.) . . 1½ gallons in 100 gallons water.
Sulsol (0·3 per cent. + wetting compound)
0·3 gallons + 8 oz. of wetting compound in 100 gallons of water.
Lime sulphur (1 per cent.). . 1 gallon in 100 gallons of water.
Liver of sulphur (0·7 per cent.) . 7 lb. in 100 gallons of water.

These should be applied at a rate of about 4 gallons of solution per 100 sq. yds., but provided the plants are thoroughly wetted there is no need to keep accurately to this figure, and the amount applied will obviously depend to some extent on the density and size of the plants. Some care is necessary in the application of all these sprays, especially Amberene, lime sulphur, and liver of sulphur. If spraying is carried out on beds covered with lath and other sheltering this should be replaced immediately after spraying. The final removal of the sheltering should be carried out at least three days after the preceding spraying, and ten days should be allowed to elapse before the plants are sprayed again. Neglect of these precautions may lead to scorching. Spraying should be carried out as far as possible on dull, but not rainy days; windy days should be avoided when possible, on account of the scattering of the spray; and on no account should spraying be done on really hot sunny days.

Two variations of the above spraying programme have been used with

success in recent years in Forestry Commission nurseries. At Seaton Nursery, near Aberdeen, liver of sulphur is applied as early as mid-February at a strength of 7–9 lb. per 100 gallons of water and at a rate of just over 3 gallons per 100 sq. yds. After that a lower strength, 5–6 lb. in 100 gallons of water, is applied at three-weekly intervals, at a rate of application of just over 2 gallons per 100 sq. yds. At Fort Augustus, sprayings throughout the season are carried out with Sulsol (4 lb. plus 6 oz. wetting compound in 100 gallons of water). This is applied at a rate of 4 gallons per 100 sq. yds. for seed-beds, and 3 gallons per 100 sq. yds. for transplant lines.

In the recommendations made above several alterations from those given originally will be noticed. In the first place the use of a stronger solution for the first spraying is no longer advised. In the recent experiments the early spraying has not proved so important as it was originally thought to be. Though it is absolutely necessary to start early, there would now appear to be no especial virtue in using extra strong sprays, especially when the use of these means a risk of scorching. Secondly, precipitated sulphur, which was included in the original spraying recommendations, is now omitted. It was always known to give a poorer control than the other substances recommended, and the only fact in its favour was its low cost. In this it is now rivalled by lime sulphur; and the reduction in the advised strength of Sulsol has made the use of that substance much less expensive, so that there is no longer any reason for retaining a substance giving poor control merely on account of its low cost.

In the course of the spraying experiments a certain amount of further information was collected on the effect of the disease on the plants, and on the effect of spraying in mitigating this. Except in seed-beds less than one year old, the effect of *Meria* is usually to weaken, rather than to kill the plants, and a heavy *Meria* attack normally results in an increase in the proportion of very small plants. In a lighter attack, the disease, though it may look quite striking because of the browned needles, has been found to have very little effect on the health or final size of the plants. It is probable that the final effect of the disease depends a good deal on the weather in the latter part of the growing season. If weather in August and September is favourable for growth, plants previously quite stunted by the disease will be enabled to grow away, and, by the end of the season, the effect of the disease on the size of the trees will not be at all marked. If, on the other hand, growing conditions during the last part of the season are bad, trees crippled by the disease will remain small, and the effect will still be apparent when the plants are lifted. Spraying has therefore mainly to be justified on the grounds that more large plants, or, what is perhaps more important, fewer small plants are produced. Even if there is no virtue in having larger sizes for planting, there is considerable advantage in not having small plants which would have to be kept in the nursery an extra year to reach planting size. Calculations which are too long and complex for inclusion here have been made, in which the value of plants below 6 in. in height (2-year-old seedlings) was taken to be about half that of plants above that height. On this basis, and allowing for the cost of the treatment, spraying,

when a bad attack was experienced, was found to have quite an appreciable effect on the value of the crop as lifted from the seed-bed. This increase of value varied from 8 to 88 per cent. On the other hand, as has already been pointed out, if the *Meria* attack is slight, or if the growing conditions in the latter part of the season are favourable, the effect of spraying and therefore the increase in value of the sprayed plants may be negligible. Also, of course, if the nursery is more or less *Meria*-free there will be less attack on the rising one-year beds, in which the disease is capable of causing a large number of deaths, and which are not amenable to spraying. There is considerable evidence now to suggest that regular spraying of all the European larch in a nursery will eventually free that nursery from the disease; and it is possible that, if there are no larch near the nursery, and if no further infected plants are introduced, spraying could be discontinued after five or six years. In any case it must not be forgotten that a new nursery or one still *Meria*-free can be kept free from the fungus if European larch is only introduced in the form of seed, always provided there are no European larch-trees in its immediate neighbourhood. This precaution, when it can be adopted, is definitely preferable to spraying.

In conclusion, thanks are due to the Forestry Commission, who have financed this investigation, for permission to publish these results, and also to officers, foresters, and others connected with the Commission who have carried out most of the routine work in connexion with the experiments on which this note is based.

## LITERATURE REFERENCE

(1) Peace, T. R., and Holmes, C. H.: '*Meria laricis*, the Leaf Cast Disease of Larch.' *Oxford Forestry Memoir No. 15*, 1933.

# FURTHER NOTE ON THE NATURAL REGENERATION OF OAK ON CLAY SOILS IN SOUTH-WESTERN ENGLAND

BY BARRINGTON MOORE

(Collaborator, United States Forest Service)

IN the summer of 1932 and 1933 a series of enclosure experiments was carried out to find some of the causes for the scarcity of natural regeneration of oak in the oak-ash-hazel forests on clay soils in south-western England near Taunton. The results, published in this journal,[1] showed that the acorns, where exposed to mice, were completely destroyed, but that, where protected against mice, germination and establishment were excellent.

The experiment was carried a step farther in 1933 to 1935 to see how far mice are responsible for damage to young oaks which happen to come up from the occasional acorn that they miss. In May 1933, 24 oak seedlings, 1 year old, were planted, 12 in the enclosure fenced against rabbits but exposed to mice, and 12 outside the enclosure exposed to rabbits as well as to mice. The plantings were made as inconspicuous as possible, with small holes, and the leaves replaced around the seedlings, because it is sometimes asserted that rabbits are attracted by the changes on the ground, and by the new plants. There were no failures.

During the summer of 1933 there was plenty of evidence of mice on the area. Outside of the enclosure, as many as four new holes were found at one time around a single seedling, yet the seedling was not touched.

When the last examination was made in 1933, on 6 October, seven of the unprotected plants, or 58 per cent., had been nipped in varying degrees. Not one of the plants protected against rabbits had been disturbed. No observations were made in 1934.

By August 1935 the contrast between the young oaks exposed to rabbits and those protected from rabbits, but exposed to mice, was very striking. Outside of the rabbit enclosure only a quarter of the original number were holding on, badly nipped and crippled. Inside of the enclosure the entire number were living; two-thirds were classed as healthy, and one-third as fairly healthy, the latter subject to more competition from the under-vegetation than the others. Only one had been nipped, but not severely. The chief danger, when rabbits are kept out, is smothering by the rather luxuriant vegetation. But, if the mice were eliminated, there would probably be so many seedlings that a fair number, perhaps enough for natural restocking, would come through. As it is, with the mice eating the acorns, and the rabbits killing such seedlings as come up, it is no wonder that natural regeneration of oak is scarce.

[1] Moore, Barrington: 'Oak Woodlands on Clay Soils in South-Western England and Scarcity of Natural Regeneration of Oak.' *Forestry*, vol. vii, No. 2, 1933, pp. 85–92.

# SOCIETY'S AND OTHER NEWS

## NOMINATION OF OFFICE-BEARERS AND COUNCILLORS

MEMBERS are reminded that nominations for election of office-bearers and councillors at the Annual General Meeting in 1937 must be in the Secretary's hands by 31 October next. There is no special form of nomination, the only requirement being that the nomination must be in writing and be signed by two Professional Members (i.e. Fellows or Associates).

Nominations are required for the following:

*Office-bearers*, to hold office for one year: President,* Vice-President,* Editor of Journal,* Business Editor,* Secretary and Treasurer, and Auditor.

*Councillors*, to hold office for two years: THREE.

A list of those now in office will be found at the beginning of this number. The retiring office-bearers and Councillors are all eligible for re-election.

## LT.-COL. FOTHRINGHAM: AN APPRECIATION

LT.-COLONEL WALTER I. J. SCRYMSOURE-STEWART-FOTHRINGHAM, of Murthly and of Fothringham, died on 7 April 1936, in his seventy-fourth year. He was one of the original Forestry Commissioners, appointed by His Late Majesty on the passing of the Forestry Act of 1919, and continued to serve in that capacity until the date of his death. It can, in fact, be said that he died in harness, for his last official inspection was at Kielder Forest as recently as 28 February last, in weather as cold and inclement as it could well be.

Colonel Fothringham, as he was known to his brother Commissioners and the staff of the Department, will be sadly missed, as one of his rarely distinguished, simple, and kindly charm of character cannot fail to be missed in these times in which we live. Such men are becoming rare and more rare as the years go by, and our country-side can ill spare them. His whimsical humour, penetrating common sense, and very obvious dislike of all things showy and superficial inspired affection and confidence. As Chairman of the Forestry Commissioners' Estate and Holdings Committee, the wide knowledge of men and land which he applied, with a firm sense of fairness, to every problem brought before him, has been of the greatest help to those responsible for the management of the million acres of land now administered by the Department in Great Britain. The full tale of his public service is perhaps fully known to few, but for his life-long services to forestry, British foresters owe a deep debt of gratitude. Those who have been privileged to work closely with him during the past sixteen years of State Forestry are at least able very fully to appreciate the sterling quality of his aid in the not very easy task laid upon the Forestry Commissioners by the Act of 1919.

Colonel Fothringham loved his woods and tall trees at Murthly, but his shrewd and kindly regard stretched out far beyond the limits of his own possessions to embrace all the country-side and its denizens large and small. Forestry and foresters have indeed lost a friend. W. L. T.

* Each must be a Fellow resident in Great Britain.

## MR. W. DALLIMORE

Mr. Dallimore, who was President of this Society in 1933, retired from the position of Keeper of Museums of Economic Botany, Royal Botanic Gardens, Kew, on 31 March. He entered Kew as a student-gardener in 1891, and ended in the important post he has just vacated, where he had to deal with world-wide questions relating to all kinds of plant products. Few men are better known in British forestry and arboriculture than Mr. Dallimore. He was connected with the timber exhibitions at the White City in 1914, at Holland Park Skating Rink in 1920, and at Wembley in 1924, while his books on *Trees and Shrubs*, *Pruning Trees and Shrubs*, and that written in collaboration with Mr. A. B. Jackson, *A Handbook of Coniferae*, are well known. He was awarded the Veitch Memorial Medal and the Victoria Medal of Honour by the Royal Horticultural Society, while he received the Imperial Service Order in 1935. Members of this Society will wish him a long and happy retirement. His new address is 'Kew Cottage', The Ridge, Bidborough, nr. Tunbridge Wells, Kent.

## CORRECTION

In the article on 'The Fourth British Empire Forestry Conference', p. 140, vol. ix (2), it was stated that the Chairman of the First Conference in London, 1920, was Sir Francis Acland. This was an error, the Chairman on that occasion being the late Lord Lovat.

## THE BRITISH ASSOCIATION FOR THE ADVANCEMENT FOR SCIENCE

The meeting of the British Association takes place in Blackpool on 9–16 September. A programme is being arranged for the Forestry Sub-section K. It is intended, among other items, to hold a discussion on the 'Utilization of Home-grown Timber'. Lord Clinton will preside, and a number of contributions have been promised by men connected with the Forestry Commission, the Timber Trade, &c. This discussion is fixed for Friday, 11 September. A number of papers on other subjects of forestry interest will be read on Thursday, 10 September, and Monday, 14 September, and excursions are being arranged to forest estates and wood-using industrial establishments.

The Secretary of the Section is Mr. T. Thomson, Forestry Department, University College of North Wales, Bangor, who will be glad to hear from any persons wishing to read suitable papers on subjects connected with Forestry. It is hoped that as many members of the Society as possible will attend the meeting.

Particulars of the conditions of membership, programmes, &c., may be obtained from the Secretary, British Association, Burlington House, London, W. 1.

# REVIEWS

*A Text-book on Forest Management.* By M. R. K. Jerram, M.C. Pp. 152. Chapman & Hall, Ltd., London, 1935. Price 10*s.* 6*d.*

Review by R. Bourne

THE object of this book is 'to bring to the notice of the student, in as brief and simple a manner as possible, all matters of primary importance relating to the subjects which are commonly dealt with under the term Forest Management'. The foundations of Forest Management, Preparation and Control of a Working Plan, and Forest Finance are the respective titles of the three parts into which the book is divided.

In Part I an exposition is first given of the theory of the normal forest. Small diagrams are employed in an attempt to clarify the subject, but, in fact, only serve to perpetuate views of continental authors which the reviewer considers incorrect. For instance, no distinction is made between the portions of the growing stock producing respectively the final and intermediate yields, nor is any recognition given to several of the essential differences in the normal stocking of regular and irregular forests. One consequence is that the author's subsequent comments on the relationship of growing-stock, increment, and yield, and on the methods of yield regulation described, are not always to the point. The other result is that the student is not given a good foundation on which to base his further study of the subject.

Part II, which covers 28 pages, is a brief outline of the general problem of Working Plans. Procedures are referred to rather than described, but attention is drawn to selected literature on different aspects of the subject. It is assumed that the student will be given detailed instruction in the field.

In Part III the author has concentrated on the valuation of unit woods, ignoring to a large extent the many differences which arise in the valuation of series of age gradations. So far as he has gone, he has closely followed the exposition of the subject developed by C. E. Simmons while on the staff of the Imperial Forestry Institute, Oxford, and, in the circumstances, it might have been as well if he had given the latter's exposition in full.

In general, it must be recognized that, in covering such a wide field in a short space, the author has attempted a difficult task, and, apart from the shortcomings in the exposition of the theory of the normal forest in Part I, has gone far in achieving his purpose. The book is clearly printed. The first issue contained a considerable number of misprints, partially corrected by an errata slip. We understand, however, that a revised issue is now available.

*A General Introduction to Forestry in the United States, with special reference to Recent Forest Conservation Policies.* By Nelson Courtlandt Brown. Pp. 293, with illustrations. Chapman & Hall, Ltd., London, 1935. Price 16*s.*

Review by W. L. Taylor

PROFESSOR NELSON COURTLANDT BROWN, whose comprehensive knowledge of American forestry is acknowledged, and who has also travelled extensively in the forest regions of Europe, including those of Great Britain, has produced a general treatise on forestry in America in the form of a remarkably complete conspectus of the

subject in all the wide range of its implications and technicalities. He has done this in the short space of 293 pages. The result is an up-to-date, lucid, and entirely readable book, aptly illustrated by photographs and printed in clear type. It is a work that no forest officer can fail to read with interest and profit.

The early chapters are devoted to the history, economics, and importance of forestry, which is defined as the 'best use of the forest' and the 'art and science of managing our forests and converting the produce to best serve mankind'. The author's definitions apply also to British forestry with the addition that we, in Great Britain, must create as well as manage and convert. He pays grateful tribute to lessons drawn from the centuries of systematic forest management in Europe, the methods of which are being adapted to meet American conditions. The forceful picture of the life awaiting a young man who adopts forestry as a profession ought to be read and taken to heart by all who feel a desire to make forestry their life work. Proper emphasis is laid upon the qualities called for, including a sound physique, careful training, great common sense, a real love of the work, and a spirit of public service. The true professional aspect of forestry has never been better or more vividly described.

The discussion of forestry technique covers all the ground: the tree as a living organism, the influence and types of forests, the factors determining the choice of species, forest protection, measurement, and valuation, silvicultural operations, utilization and timber preservation. The greater part of the chapter on forest protection is devoted to forest fires, their causes, prevention, control, and supervision. This is in itself a most weighty subject, and the appalling waste of material, human life, and property involved in the United States alone since 1825 is briefly but clearly depicted. The devastation extends to millions of acres of forest, and so late as 1933 the great Tillamook fire resulted in a loss estimated at more than 40 million pounds. No less than 41 per cent. of the forest fires in America are attributed to lightning, and in 21·5 per cent. of the outbreaks smokers are adjudged the culprits. Excepting the use of aeroplanes, made possible by the vast areas patrolled, no methods of fire fighting are described that are new to Great Britain, but, in view of the serious hazard to which newly-planted British forests are subject, the information afforded is valuable both from a practical standpoint and in illustration of the terrible havoc resulting from carelessness and neglect of precaution.

It is apparent that the United States Forest Service now lose far fewer opportunities of securing natural regeneration than formerly, it being recognized that this is nature's way and the best in all appropriate circumstances. The methods adopted are clearly set forth and will repay study. A comparison of American *versus* European systems of silviculture concludes with the words: 'We cannot, in this country, directly apply foreign intensive theories of management until higher prices for forest products are obtainable and we know more about the art of growing trees.' The author is plainly telling us that silvicultural purism can be purchased at too high a cost. Artificial reproduction of forests, nursery work, planting and subsequent tending, are of necessity, in a work of this size, rather briefly touched upon. Nevertheless, the chapters are packed with essential information. Pruning receives notice in a few words only, and the growing practice in Great Britain of selecting trees, in young stands, for pruning for clean poles and the final crop, evidently finds no large place in American forestry.

The development of national forest policy and the history of the United States' Forest Service are clearly traced, and the importance of the National Forests as models of forestry practice and in the betterment of the social and economic conditions of local communities are themes that cannot too often be pressed home.

There are in the United States twenty-four professional schools of forestry, and the author gives an interesting analysis of the subsequent employment of the graduates. It is stated that approximately 80 per cent. of the graduates in forestry are engaged in some phase of forest activity. Research centres on the Forest Products Laboratory at Madison.

The final chapters deal with the Roosevelt programmes and emergency conservation work and lead to a most interesting account of the great Plains Shelter Belt project and the place of forestry in regard to land utilization from the point of view of national planning.

Dr. Brown takes no narrow view of the importance of forestry in the national economy of his country. Forestry has an uphill task in all but lip-service in most countries not imbued with a forest sense and, in addition to its technical merit, this book radiates a reasoned and valuable missionary spirit.

There is a bibliography, references for more extended reading, and notes on the National Recovery Act (Lumber Code and Forestry), and a list of the important native trees are included as appendices.

*Logging-Transportation.* By Nelson Courtlandt Brown. John Wiley & Sons. Chapman & Hall, Ltd., London, 1936. Price £1.

Review by A. H. Lloyd

THIS is a companion volume to Professor Courtlandt Brown's *Principles and Practices of Logging in the U.S.A.*, published in 1934. The two volumes together form the best and most comprehensive work on this subject at present available. The great diversity in topography, climate, and forests in the wide area covered by Professor Brown's survey of timber extraction in the U.S.A. and Canada, renders his task of producing a general text-book extremely difficult. In the first volume the descriptions of widely different methods of extraction, evolved by different sets of conditions, show the importance of a thorough appreciation of local conditions before attempting to introduce methods which have proved successful elsewhere.

During the past quarter of a century, mechanical methods of handling timber have undergone surprisingly rapid changes and improvement, and the text-book now under review gives an opportunity to measure the progress made since 1913 when R. C. Bryant's *Logging* was published and became the recognized authority on American logging practice. These changes are largely due to improved mechanical devices, particularly with regard to road transport vehicles; but the change in forestry practice from wholesale exploitation to selective felling, particularly in the State Forests, and the diminishing areas of large-sized timber in virgin forests are also important factors in the change in extraction methods.

The usual text-book division of timber transport into two separate operations has been followed. The first operation is extraction in the forest or the skidding and hauling from the felling site to a collecting point, called a 'cold deck' or 'skidway', the second operation being the main haul from the collecting point to the final destination. A useful comparative analysis is given of costs of animal dragging and tractor skidding. This shows greatly to the advantage of the tractor and, although horses are still used extensively, the modern track-laying or 'Crawler' tractor with its great flexibility and speed is replacing horse-dragging except in a few particular localities. In addition to actual skidding work the tractor is used for road-grading and construction, loading and hauling wagons, and to provide power for felling saws and even for portable saw-mills.

The latest type of logging tractor has little resemblance to the first crawler type which was built in 1904. Owing chiefly to the great reduction in fuel consumption, the Diesel-driven tractor is rapidly replacing petrol-driven models. The modern skidding unit consisting of a Diesel tractor, fitted with a powerful winch and a 'Fairlead arch', enables one man to do the work of twelve or more men with horse teams. In this type the cable from the tractor winch passes through a pulley-block in the top of the Fairlead arch and ends in a number of bunch lines. By putting the winch into gear and moving slowly forward the logs attached to the bunch line are automatically pulled up together underneath the arch and raised ready for removal. When the Fairlead arch is fitted with crawler tracks this unit is said to be able to operate both in rough and in swampy ground which would be inaccessible to any other form of wheeled transport.

The simple skidding device, known as 'chaining', and consisting of a long $\frac{3}{8}$-in. chain passing round a number of bundles of pulpwood in succession, and drawn by horses, might be used for the extraction of short cordwood and cogwood under certain conditions in this country.

Cable-hauling systems are still used in steep precipitous country and also in swampy localities, but owing to the damage to the forests caused by the skidding-cables the method is being replaced wherever possible by tractors. Chutes and 'flumes' (wet slides) are limited chiefly to the transport of pulpwood and sleepers, and modern forms of slides and chutes are described in detail. Various types of sleds and 'bummers' are also shown for dragging and hauling. 'High-wheel' trailers are being replaced rapidly by the Fairlead arch type.

Railways still form the principal means of transport in the large operations of the West and wherever large and regular supplies are required irrespective of climatic conditions, but for hauls up to 70 miles, motor lorries, or 'trucks', are now competing seriously with logging railways, especially of the narrow-gauge type. A great increase in the use of motor lorries, with or without timber trailers, has followed the improvement of American roads. New types of lorries and trailers specially designed for log haulage are described and illustrated, with useful analyses of running costs. Some of the loading methods described in Chapter VI are of wide application and might be tried with advantage, under suitable conditions, in English forests.

The wide range of extraction methods covered in these two volumes necessitates brief treatment in many instances, but the comprehensive bibliographies, of some thirty pages, included in each volume, indicates the source of more detailed information if required.

'*Beitrag zur Kenntnis der Fichtenformen und Fichtenrassen.*' By Professor Dr. K. Rubner. Tharandt. *Tharandter Forstliches Jahrbuch*, vol. lxxxvii, No. 2, pp. 101–176.

Review by W. H. Guillebaud

In view of the copious literature that has appeared in recent years on the races of Scots pine, European larch, and other forest trees, it may seem at first rather strange that Norway spruce, *Picea abies* (*excelsa*), should have been left out in the cold. But, as Professor Rubner points out, there are a number of reasons to explain this apparent neglect. In the first place, the stems of spruce are almost invariably straight, no matter what the origin may be, and so the question of racially crooked stems, which is so

important in Scots pine, does not arise. Secondly, the crown form in spruce is perplexingly variable, and there is a lack of obvious distinguishing features available for purposes of classification.

There are, however, other properties besides form of stem which play an important part in the silvicultural development of spruce and deserve careful investigation, namely, susceptibility of young plants to late frost, rate of growth in youth, and liability to damage from snow, hoar frost, and ice at high elevations in mountain regions.

Professor Rubner has devoted the article under review to a comprehensive study of spruce types in the central mountains of Germany, namely, the Glatzer Bergland, Riesengebirge, Erzgebirge, Fichtelgebirge, the Forest of the Upper Palatinate, the Bavarian Forest, and the Bavarian Alps between the Inn and the Isar. Some observations were also made in the Harz Mountains and the Thuringian Forest. The article is in two parts, Part 1 dealing with the forms of the spruce crowns and the distribution of the different types in the above-mentioned mountain regions, and Part 2, in which Rubner gives the results of his studies of a number of plots established with spruce from different elevations in the central mountains of Germany. The author and the publishers are to be congratulated on the profusion of photographic illustration which adorn the paper; no fewer than 66 photographs are reproduced, and these add greatly to the interest as well as to the value of the text.

The crown forms of spruce, which form the subject of Part 1, have already been studied and classified by the Swedish forester Nyls Sylven. As the types worked out by Sylven have been accepted by Rubner, and as a knowledge of them is necessary to the understanding of the latter's paper, the reviewer considers it desirable to make a free translation of Sylven's classification as stated in the present paper.

1. *Comb Type* (*Kamm-Typ*). The secondary branches are long and pendulous and are easily swayed by the wind. These pendent branchlets are not confined to the upper part of the crown, but occur also in the middle and lower part of the tree.

2. *Brush Type* (*Bursten-Typ*). These are distinguished from the comb type by the shorter secondary branches of the upper and middle portions of the crown. Also, these are not loosely pendent but are more brush-like. The lateral twigs of the lower, and often the middle portion of the crown also, tend to flatten out.

3. *Plate Type* (*Platten-Typ*). The main branches as well as the lateral twigs are spread out horizontally. The characteristic feature of this type is that the flattening is not confined to the lower part of the crown, but extends throughout its whole length.

4. *Band Type* (*Band-Typ*). Secondary branches short, thick, and scarcely pendulous. (According to Rubner the Band spruces can be included among the brush type of crown forms.)

As Rubner points out, it is difficult to employ this classification in even-aged stands where a view of the whole crown is rarely possible, and the issue is further complicated by the presence of transitional types in stands of mixed origin. The crown types cannot be distinguished satisfactorily in young stands, as a rule not at least until the thirtieth to fortieth year.

As regards the distribution of these crown types in the German forests, Rubner finds that at least 80 per cent. of the trees belong to the brush type, which is thus by far the commonest of the four categories. Next in importance comes the comb type which occurs chiefly at the lower elevations and in hollows and fertile valleys, though even in these situations it is much less common than the brush type. Sylven has produced evidence to show that in Sweden the comb type is the fastest growing, probably because of the more efficient utilization of light of this form of crown. Spruce of the

plate type are much less common. They are found chiefly at the highest elevations in mountainous regions, in association with spruce of the brush type, and at certain elevations in the Erzgebirge and Fichtelgebirge, where damage from hoar-frost is very severe. It will be seen that there is a certain degree of association between the forms of spruce crowns and locality conditions, but how far these are racial characters has not yet been fully established.

The problem of the very narrow, spire-like spruce crowns which are a feature of spruce growing in high latitudes or at high elevations is fully discussed by Rubner. These trees have abnormally short main branches which in some cases are strongly drooping, when they are known as *Spindelfichte*; while to the trees whose branches are merely shortened but not drooping the name *Watzenfichte* is given. Apparently trees of this curious habit occur only under extreme climatic conditions and even then are by no means universally present. Entire blocks may consist of these spire-crowned spruces; for example, there is a famous stand of this sort at Paneveggio in the Tyrol; but often they occur as single trees scattered among spruce of a more normal crown form. The spire crown is obviously well adapted to conditions of heavy snowfall: the snow is unable to lodge on the short, often pendulous branches, and there is little or no overlapping of the branches of adjoining trees. The curiously sporadic occurrence of spire spruces makes it difficult to account for their origin on any theory of natural selection and the evidence strongly suggests that they have been produced partly as a result of shoot killing by late frost, and partly as a result of mechanical injury. What happens in many cases is that the twigs and needles become coated with ice as a result of repeated thawing and freezing of snow falling on the branches, and when the frozen crowns come in contact through the action of wind, breakage occurs, leading eventually to a short bushy development of the primary branches. Another important contributory cause is the action of late frosts, which by killing the young shoots prevent the normal development of the side branches, the terminal buds, owing to their later flushing, usually escaping damage. The occurrence of entire stands of spire spruce is attributed by Rubner partly to the fact that they have originated from a relatively small number of mother trees and so have a generally similar genetical constitution, and partly to uniform climatic conditions. Other modifications of the spruce crown, due to climatic conditions, occur locally, such as the *Hochwaldfichten*, found at high elevations in the Bavarian Forest, which with their drooping, enveloping crowns resemble the habit of a cypress. The form in this case is ascribed to the great age of the trees and to the long-continued action of frost and snow. Although Rubner does not regard the spire and similar crown-forms of the spruces growing at high elevations as primarily due to racial characters, there are undoubted modifications in the tree above a certain elevation (about 1,000 metres in the Riesengebirge). Above this elevation the trees are inherently slower growing, deeper crowned, and more slim in stem, and these properties are adaptations to the conditions. Perhaps the best evidence is provided by the comparison between native and introduced (lowland) crops of spruce at high elevations. The latter stands suffer overwhelmingly more damage from snowbreak, hoar-frost, &c., than the stands of local native origin.

Some evidence as regards these questions is provided in Part 2 of Rubner's paper, in which he describes the result of a number of provenience experimental plots which he has established at Tharandt in Saxony during the past ten years. In the first experiment described plants were raised from seed collected at varying elevations in several of the mountain regions of Germany, namely, the Glatzer Bergland, Riesengebirge Thuringian Forest, and Harz Mountains. The elevations ranged from 400 metres (1,300 ft.) in the

Harz to 1,270 metres (4,200 ft.) in the Glatzer Bergland. After nine years the plots of all origins except one (Riesengebirge, 1,100 metres (3,600 ft.)) showed more or less equal rate of growth. The one exception named was much slower growing than the remainder and is regarded by Rubner as representing the slow-growing 'high elevation' race. The several lots showed a wide range as regards time of flushing, and there was no very direct correlation with elevation. The three 'very late' flushing lots came from 1,270, 1,100, and 780 metres respectively, while the three 'very early' lots came from 900, 720, and 530 metres. These observations are the reverse of general experience, and it seems probable that some of the mother stands were not of true local origin. If the heights of the early, average, and late flushing lots are averaged, a slight advantage is apparent in favour of the later flushing forms. This agrees with Münch's observations and is ascribed by him to the fact that the latter are less sensitive to shortage of water-supply.

In a subsequent experiment Rubner restricted the sources of his seed to two regions only, the Erzgebirge and Riesengebirge, and careful inquiry was made to confirm the native origin of the stands selected. The results in this case were less divergent, growth of the plots from elevations below 1,000 metres was uniformly faster than that of the plots from seed collected at over 1,000 metres in the Riesengebirge, indicating that 1,000 metres forms the division between the faster-growing 'low elevation' and slower-growing 'high elevation' races of spruce. As regards time of flushing, the Riesengebirge lots from the higher elevations flushed earlier than those from the low elevations. The Erzgebirge origins were much less uniform in time of flushing, but in general could be described as flushing very early. A late frost occurring in April 1934 severely damaged the early flushing lots, while the late flushers escaped. No relation was found between colour of cone (green or red) and the rate of growth or time of flushing of the progeny. One interesting observation based upon the experiments is that the plants raised from a single mother tree show in some cases great uniformity as regards the time of flushing and in others very wide variations in this respect, indicating that some lines are relatively pure while others are very mixed.

Rubner draws the following practical conclusions from his observations and experiments:

1. There are few really native stands left in the mountains of central Germany. The largest extent is on the northern slopes of the Riesengebirge, and even here only the old stands are unquestionably native.

2. In a mountain forest, it is not sufficient merely to require the use of the native spruce; a distinction between high elevations and low elevations must also be made. The boundary lies in the Glatzer Bergland at 1,000/1,100 metres, in the Riesengebirge at 1,000 metres, and the Erzgebirge and the Harz probably at 900 and 800 metres respectively.

3. In regions exposed to damage from hoar-frost, the plate type of spruce is to be preferred to the other types, and in thinning and regeneration fellings they should be preserved as mother trees.

4. At elevations where damage from snow or hoar-frost is likely to be serious, the selection type of forest is much preferable to uniform forest.

5. It is not necessary to separate the seed according to the cone-colour of the parent trees.

6. Late flushing spruces are useful in areas subject to frosts in April or May, but in localities subject to frosts in June the early flushing forms are better, as the new shoots become hardened off to some extent before the frost, while late flushing forms are caught at the most sensitive stage.

As regards the significance of Rubner's paper for British Forestry, nothing very significant appears to emerge. If seed is purchased from the Central Mountains of Germany, medium and low elevations are probably to be preferred to high elevations, as there are very few localities, even in Scotland, for which the slower growing 'high elevation' race would be required. The use of late-flushing spruce for frost hollows is certainly desirable, although it is a point for consideration whether more use should not be made of the frost-hardy Serbian spruce, *P. omorica*, in such situations. The point made by Rubner as to the risk of using late-flushing spruce in localities subject to June frosts is worth noting.

'*Étude forestière sur le Picca omorica* Panč.' By S. Tregubov. *Annales de l'École Nationale des Eaux et Forêts*, V (2), 1934, pp. 117–73.

Review by the Editor

GREATER interest is being taken in this country in *Picca omorica* as a forest tree, principally because of its late-flushing habit and its consequent hardiness to May, if not June, frosts. This was well shown by the mid-May frosts of 1935. *P. omorica* was dormant and escaped damage, while *P. sitchensis*, and to a less extent *P. abies* (*excelsa*), suffered damage.

The article under review brings together a considerable amount of information regarding the species in its natural habitat. It was discovered as recently as 1871. Its present distribution is very limited, being restricted to the vicinity of Visegrad on the Drina, near Belgrade. This contrasts with its wide distribution during Tertiary times. The climate of its present habitat is typical of mountain conditions in a continental zone. The winter is cold, and snow lies until May on the northern slopes, while the summer is relatively cool for continental conditions. The rainfall is about 40 inches per annum. The soils appear to be mainly basic, but it also occurs on silicious soils and peat. The typical station of *P. omorica* is on the steep, rocky slopes of the mountains between 3,500 and 4,700 feet and on the north side. On the southerly slopes, oak forests occupy the valley bottoms, and up to about 3,000 feet. At the upper limit, beech occurs in mixture, then follows a zone of *P. silvestris*, and at about 4,000 feet a mixed forest of *P. silvestris*, *Picea abies*, and beech. Above this zone there is open moor covered with dense *Genista radiata*.

Most of the natural stands of *P. omorica* are relatively young, about 70 years old and even-aged, regeneration occurring either after clear cutting or fire. Height growth is relatively slow up to 10 years and thereafter faster. The outstanding characteristic of the species is its extremely narrow crowns, particularly in old trees. The photographs illustrating the article bring out this point very strikingly. The steep north slopes do not get much direct sunshine, and the species is said to prefer diffuse and side light, and stands are frequently very dense. It appears to be much deeper rooting than *P. abies*.

The information in this article suggests that more extensive trials of *P. omorica* should be made in this country. Its shade-bearing quality as well as its deep rooting and frost hardiness are points in its favour. Its timber appears to be similar to Norway spruce.

'*Heidebekämpfung in Nadelholzkulturen mit ungeöltem Kalkstickstoff und Hederich-Kainit* (*Staub-Kainit*)' (Eradication of Heather in Coniferous Planta-

tions by means of Unoiled Calcium Cyanamide and Hederich-Kainit (Ground Kainit)). By E. Brückner and W. Bujakowsky. *Forstarchiv*, Heft 8, 1936, pp. 121–5.

Review by A. B. Stewart

THE widespread occurrence of heather on afforestable land in this country, in many instances on soils which appear to be intrinsically suitable for spruces, and the initial check to growth of spruce which is associated with heather make the question of its eradication one of importance. This paper describes methods and results in Germany.

*Quantities of Fertilizer required.* The quantities necessary to kill 80–90 per cent. of the heather will depend largely on the age of the plants, but for a close heather cover (over 5 years old) quantities of the order of roughly 5½ cwt. calcium cyanamide per acre or 12 cwt. ground kainit per acre may be regarded as normal dressings. Ground kainit is less effective on certain soils and is generally less reliable than the cyanamide treatment. Preliminary experiments are to be considered advisable if it is intended to employ kainit.

*Time of Application of Treatment.* The best results are obtained when treatment is applied when the heather is in bloom (about the middle of August). Both substances act on the surface of the leaves and flowers, and the powder adheres most readily when the plants are moist—preferably with dew. Quiet, dewy mornings during a dry period are most suitable for the application of the treatments.

*Technique.* It is important to use unoiled, finely powdered cyanamide. This may be sprinkled over the heather by hand, care being taken not to let the powder land on the young trees. Details are also given of sprinkling apparatus ('Blowers') suitable for applying cyanamide, and attention is drawn to precautions which should be taken for the protection of the body in the handling of cyanamide. Ground kainit is most conveniently applied by hand.

*Effect on the Growth of the Young Trees.* Destruction of the heather in the foregoing manner is found to be effective in hastening the growth of the young trees and keeping the heather in abeyance for about ten years. The treatment applied, in addition to destroying the heather, has also a certain residual manurial value which helps the early growth of the trees.

*Economic Aspects.* Details are given showing that the cyanamide treatment costs approximately 58 marks (£2 18*s.* at par) and the kainit treatment approximately 30 marks (£1 10*s.* at par) per acre.

At current British prices, approximately £7 5*s.* per ton for calcium cyanamide and approximately £3 per ton for ground kainit, there will not be so much difference in the costs of the two treatments. The materials required will cost approximately £2 per acre for cyanamide and £1 16*s.* for kainit; to this labour costs and freight charges will, of course, have to be added. The latter will be slightly heavier for kainit than for cyanamide, and in view of the fact that the cyanamide treatment has been found to be generally more effective than kainit the cyanamide treatment would appear to be the more worthy of consideration in this country. The costs given above are based on the assumption that 80–90 per cent. of the heather is being eradicated. The problem of whether a less complete eradication at a lower cost per acre would prove to be of sufficient practical value to British forestry to warrant the application of light dressings of cyanamide might be worth investigating, because the principal drawback to the treatment as described is the cost.

*The Oak in Denmark.* Parts I, II, and III. By L. A. Hauch. Simpkin Marshall, Ltd., London.

Review by the Editor

MR. L. A. HAUCH, the well-known Danish forester, gives in this publication the fruits of sixty years' experience in the cultivation of oak in Denmark. Our first wish is to send greetings to this veteran forester, and thanks for publishing his work in English for the benefit of English-speaking foresters.

The author deals with each stage in the cultivation of oak, garnishing his views with many reminiscences. He advocates a more extensive use of oak in Denmark, and he dwells on its suitability for a wide range of soils. He has made a special study of the differences in type from acorns collected in different parts of Europe, necessarily south of Denmark. He is strongly of the opinion that Danish acorns are best. Oak from southern origins tend to produce summer shoots more freely which are frequently infected with mildew. He advocates sowings in cultivated trenches under a shelterwood, and considers a dense crop essential—over 80,000 seedlings per acre. As sowings are made in spring—because of losses from game in autumn sowings—special care is necessary to ensure that germination is not lost during storage. The type of acorn-storage house described is similar to that often used in this country. The dense crops advocated necessitate an early thinning—about the tenth year. This, however, should be done cautiously. It is interesting to note that he considers that the aim of the thinning should vary with the origin of the acorns. In stands from Danish acorns, dominant stems are generally deficient in number, hence the thinning should be directed to increase their number, while in stands from foreign acorns, there are usually too many dominant stems and it is necessary to diminish their number. Later, before grass comes in, an understory, preferably of beech, should be introduced.

'*Storage of some Coniferous Seeds.*' By L. V. Barton. *Contributions from Boyce Thompson Institute*, vii (4), 1935, pp. 379–404.

Review by the Editor

THIS paper reports the results obtained from different methods of storage of seed of *Pinus taeda*, *P. caribaea*, *P. echinata*, *P. palustris*, *P. resinosa*, *Picea abies*, and *P. canadensis*. The methods studied included storage in the open at ordinary temperatures, and at 5° C., —5° C., and —15° C., in sealed flasks, in vacuum flasks, and the effect of drying before storage. The seed was stored for periods up to 7 years, and was sown in soil immediately and also after storage for 1 to 3 months in granulated peat at 5° C.

The results showed that the seed of all species lost their vitality in 1 or 2 years under open storage at ordinary temperatures. Sealed storage at 5° C. or —5° C. to —15° C. was effective in maintaining vitality for periods up to 7 years. This was marked in *P. taeda*, *P. caribaea*, *P. echinata*, *P. resinosa*, and less marked in *P. palustris* whose seed vitality decreased under all methods, while *Pinus ponderosa*, *Picea abies*, and *P. canadensis* only stored satisfactorily for 4 to 6 years in refrigeration rooms at —5° C. and —15° C. Artificial desiccation by CaO was harmful. Vacuum storage improved vitality at ordinary temperatures. Storage in granulated peat for short periods before sowing was beneficial in most instances, but was not necessary in *Pinus resinosa*, *Picea abies*, and *P. canadensis*.

*Land Settlement. A Report prepared for the Carnegie United Kingdom Trustees.* By A. W. Menzies-Kitchin. T. & A. Constable, Ltd., 1935.

Review by the Editor

THE subject of land settlement, and in particular small-holdings, has been dominated everywhere by political and social rather than economic considerations, hence this unbiased economic survey is to be welcomed. It is interesting to note, however, that the Carnegie Trust have not accepted altogether the conclusions of their investigator.

A comprehensive survey of the problem has been made, and while it cannot be considered exhaustive, sufficient data are presented to support the conclusions arrived at. The subjects dealt with include: the general trend of agricultural production; variations in the consumption of different classes of foodstuffs in this country and abroad, and the influence of the anticipated fall in population in this country; trend in size of holdings; land settlement at home and abroad; types of holding in different English counties; the production of vegetables, pigs, poultry and eggs; and settlement on different sizes of holdings.

Mr. Menzies-Kitchin's general conclusion is that a large-scale policy of land settlement in this country cannot be justified on economic grounds, and if undertaken for other reasons will have to be supported, either by higher prices for foodstuffs or direct subsidies. In particular, he considers that the 3 to 5 acres whole-time holding, say specializing in pigs, poultry, eggs, or vegetables, will not be permanently successful unless considerable economies are possible on a co-operative basis, and that the mixed family farm of 30 to 50 acres is the most suitable unit of settlement. No mention is made of the Forestry Commission's small-holding scheme. The only type of small-holding favoured is the so-called subsistence type of ½ to 1 acre for unemployed workers to enable them to supplement unemployment relief. The Trustees have already decided to give grants for the development of this type, and, in spite of Mr. Kitchin's views, to assist schemes of the 3 to 5 acre type, but on a co-operative basis.

The reviewer's experience of small-holdings in different parts of the country confirms Mr. Kitchin's views.

# NOTICES

*Forest Bibliography with the Index Number 634·9 F.* Oxford, 1936.

AN international system of classifying forest literature has been under consideration since 1903, when the subject first appeared on the agenda of the International Association of Forest Research Institutes. After many vicissitudes, the task has now been completed under the aegis of that association, and the volume under notice is the English publication giving the classification which has been adopted. The chairman of the committee which completed the work is Professor R. S. Troup.

The Melvil Dewey system of decimal classification has been adopted. It was a task of considerable magnitude and difficulty to allot appropriate numbers to the subjects comprised in forestry, and the thanks of foresters are due to the committee and in particular to its secretary, Dr. Flury, for the work done. It will only be possible to judge the work when experience of the system is obtained. Numbers have been left unallocated in most sections for future development. It is almost impossible to forecast what subjects will develop most and require further subdivision, and this is likely to give most trouble in the course of time.

*Proceedings of the Conference on Forestry Research.* Ottawa, 1935.

THIS conference was called under the auspices of the National Research Council of Canada to take stock of the general forestry position in that country, and it was representative of all the interests involved, federal and provincial, scientific and commercial. This volume contains the papers delivered and reports the discussions in them; it gives an illuminating picture of the present forestry position in Canada.

The titles and authors of the papers are as follows: 'Silviculture', by Mr. Ellwood Wilson; 'Forest Management', by Mr. A. Koroleff; 'Correlation of Silviculture and Forest Products Research', by Mr. T. A. McElhanney; 'Forest Site Classification', by Dr. C. Heimburger; 'Forest Fire Protection', by Mr. D. A. Macdonald; 'Forest Engineering', by Mr. J. O. Wilson; 'Forest Pathology', by Dr. Güssow; and 'Principles and Practices in Forest Entomology', by Mr. J. J. de Gryse.

Only a few points can be noted here. Mr. Ellwood Wilson stresses that the problem is mainly economic. While more knowledge is needed, sufficient is known to make a start in better silviculture. The difficulty is that the commercial interests are selling their timber products as too low a figure—the result of unrestricted production—and there is no margin for silvicultural methods to secure regeneration. Mr. Koroleff, on the other hand, stresses the lack of fundamental knowledge as the cause of failure to treat the forest as a self-reproducing organism and not a mine. There is no background of accumulated forest knowledge and experience such as exists in European countries with a long forest tradition, and he considers that intensive training of personnel and a wide scheme of forest research is necessary if methods are to be evolved to secure regeneration as well as utilization. Fire protection is still a major forest problem in Canada. Tribute is paid to the influence of the Empire Forestry Conference in 1923 in rousing public opinion, and it is stated that the five years that followed marked definite progress. A similar urge is now required. During the past ten years 2 million acres have been burned per annum on the average, one half being covered by young or

mature timber. The loss, including the cost of fire fighting, but not protective measures, is put at 5 million dollars.

It will be interesting to learn what practical measures follow from this conference. It is at least a good sign that it was called and that a full and frank discussion of the problems took place.

*Welsh Timber Trees.* By H. A. Hyde. Second Edition. National Museum of Wales. Cardiff, 1935. Price 2*s.*

WE welcome the second edition of this excellent book. No doubt because of the epithet Welsh, it is probably not so well known as it deserves to be. It deals with all our common trees, giving botanical characters, notes on notable trees, and information regarding the timber. The book is well illustrated, and at the low price at which it is issued should be obtained by all foresters who do not already possess it.

*Imperial Forestry Institute, University of Oxford, Eleventh Annual Report.* Oxford, 1935.

DURING the year 14 students attended for instruction. The report also records the progress being made in research in the different departments. Mr. Bourne extended his regional survey in southern England, and 2,000 square miles have now been surveyed. In the department of Systematic Forest Botany the work of botanical identification was continued, and research work on floral anatomy, systematry of Monotoideae, Cricket-bat willow, and elms was carried out. In the department of the Structure and Properties of Wood, research work on the woods of the Sterculiaceae, and on Tertiary Dicotyledons was done. In the departments of Forest Pathology, the work on frost damage, elm disease, *Meria laricis*, poplar canker, and other diseases was continued, while under Forest Zoology the pine weevil, the pine shoot moth, the oak tortrix moth, chafer beetles, &c., were studied further. Mr. A. H. Lloyd continued in charge of Forest Engineering and Utilization.

*Forest Products Research Records*, 5–8. H.M. Stationery Office. Price 6*d.* each.

THE first of the above new series issued by the Forest Products Research Laboratory were noticed in the last number. The following are the titles that have appeared since:

No. 5. 'The Moisture Content of Timber in new Buildings.'

No. 6. 'The Properties of an African Mahogany (*Khaya anthotheca* C, DC.).'

No. 7. 'The Properties of Mansonia (*Mansonia altissima* A. Chev.).'

No. 8. 'Strength Tests of Structural Timbers', Part 2. General procedure of selecting and testing joists, with data on British Columbian Douglas fir, *Pseudotsuga douglasii* Carr.

# ADDRESS TO THE SOCIETY[1]

## BY SIR ALEXANDER RODGER

I SPOKE last year on the desirability of all those interested in forestry doing their best to interest the public in the subject and enable people to understand what an extremely useful thing forestry was to any country. It is taking a very long time for the forestry sense to be diffused among the people of this country and for the fact that State forests are an essential part of every well-regulated country to penetrate to the national consciousness. I referred last year to the powerful and, perhaps in our view, somewhat extravagant methods that are in vogue in America, and it is probable that measures of the kind would command little sympathy in Great Britain. Thinking this matter over it struck me that many people in England do *not* want the face of their country changed. I was in Sussex a fortnight ago when the weather was fine and hot, and I must confess that I have never seen any country-side more beautiful than that typical English landscape in the middle of May. It may very well be that many people think that we have enough trees and that no country could possibly be more beautiful than our own during the spring. Poets and writers, including Shakespeare, have pointed this out to us, and I think that many of those who love the English country-side do not want it altered at all. At any rate those of this opinion seem to be more vocal than the others. They would far rather have valueless scrub oakwoods full of primroses, bluebells, honeysuckle, jays, and blackbirds than masses of conifers, or even close-grown oak and beechwoods. We have been in the past a very fortunate nation, and people seem to think that we can go on being fortunate, although it is a fact that large areas of our country are producing little or nothing for the benefit of the nation as a whole.

I maintain that this will not do in these modern days, and that the forester is one of those who can help to make the nation use its land to the best advantage. You see it frequently stated by opponents of forestry on a large scale, that we cannot grow straight round timber, and that the climate will not let us do so. I do not believe it, and I do not believe that the members of our Society would ever acknowledge it. You need only think of the best stands of old Scots pine, larch, Douglas fir, oak, or beech in England, Wales, and Scotland to realize that this is a ridiculous statement. It is true that they are not extensive in area, but they could have covered many square miles if forestry had been wisely undertaken long ago.

We may ask ourselves: What can we do to develop the 'forestry sense'? It is no good starting new societies. There are already too many, and I am afraid that it would be very difficult to amalgamate them because of the varying interests of the members of the different bodies. This is the time when propaganda is especially desirable, because there seems to be a growing

[1] Delivered at the Ninth Annual Meeting, held at Weasenham on 26 May 1936.

body of opinion in England which is convinced that the Forestry Commission is desecrating the country-side. The Press has of late contained many articles and letters putting forward this point of view. It looks as if the forestry interests ought to have a propaganda, or at any rate a Press Bureau of their own. It would, I think, not be difficult to recruit writers and lecturers who would bring before the public the manifest advantages of forestry. There is no need for me to tell the members of this Society about them, but one point that might be stressed is the advantages that countries like France, Germany, and Switzerland have over us in this respect. Figures of revenue, employment, and so on should be convincing, and the fortunate position of certain small communes which pay their taxes out of the communal forests could be mentioned. One very important matter, now being taken up by the recently formed National Home-Grown Timber Council, is improved methods of disposing of and using home-grown timbers. It is perfectly true that the timber trade in this country is difficult to understand and to handle, but progress is being made by means of the local marketing organizations recently started, and we may expect to see advances made in the important matter of the disposal of small timber from thinnings, and the reduction of the very high railway freights. These railway freights at present prevent a number of forest owners from sending their thinnings to the collieries at all because this can only be done at a loss. It may interest you to know that an experiment on a large scale, properly audited, is at present being conducted in Scotland by the Council, with the special object of proving to the railway companies how they can enable forest owners to sell their thinnings as pit-props without loss, if the railway rates are reduced. This matter of the disposal of thinnings is, as you may well imagine, going to be of the most vital interest to the Forestry Commission, who have in hand similar experimental extraction.

One last suggestion I would like to make is that there might be some co-ordinating body which would keep all forestry and timber interests in touch with one another in the widest sense. I have heard complaints, for example, that the forest authorities of a certain university had never heard that the Second International Conference on Timber Utilization was to be held in London in March of this year.

Our new President was, as you are aware, Chairman of the Forestry Committee of the Reconstruction Committee whose report was published in 1918. We are honoured in having as our new President a man who has done so much for British forestry. In conclusion, I would ask your permission to quote a few words from this Report: 'The fact that areas hitherto valueless have been rendered permanently habitable and productive is held to justify the initial cost, even though it may not be wholly recovered.' These wise words refer to forestry in such places as the Landes of France and the high moors of Belgium, and we may well take them to heart in this country.

# GWYDYR FOREST

BY A. P. LONG

## INTRODUCTION.

GWYDYR FOREST, one of the units of the Forestry Commission, is situated in Caernarvonshire, North Wales, with Bettws-y-Coed as its centre. It takes its name from the Gwydyr Estate which contributed the first section of the forest in the year 1921. Since that date there have been many additions of land in the country through which flows the River Conway and its tributaries, the Lledr and Llugwy, so that the total area at the present time amounts to 18,189 acres.

This land is by no means all forest land. It was formerly used as sheep farms with grouse moors above and pasture in the valleys, whilst on the rocky slopes there were originally woodlands representing about 15 per cent. of the total. The policy of management, coupled with the unplantability of much of the higher land, takes advantage of the various types of utilization, and the forecast of the forest in its final stages subdivides it into 11,547 acres of plantation; 4,732 acres of unplantable land to be continued as sheep walks and grouse moors; and 1,910 acres of agricultural land to be retained as holdings and farms.

## DESCRIPTION OF THE LOCALITY CONDITIONS.

Gwydyr lies about 10 miles to the east of the mountainous Snowdon range, and it is made up of an elevated plateau at an altitude of approximately 800 feet to 1,000 feet which is broken by volcanic ridges and peaks rising to an elevation of 2,800 feet, and deep steep-sided valleys running down to an elevation of 20 feet above sea-level.

The climate is humid with a heavy rainfall of normal distribution for this country varying from 48 inches per annum in the valleys to probably nearer 100 inches on the higher ground. Though common in winter, falls of snow usually are not heavy, nor does snow lie for long periods except on the highest peaks. Frost in the winter may be fairly severe and prolonged, but it does not commonly occur at unseasonable periods except in elevated depressions. Prevailing winds are from the south-west and frequently reach gale force. Protracted periods of north-east and east winds in the spring are uncommon. In general the climate may be described as mild, humid, and very suitable for the growth of trees. There is a well-marked spring rather later than the normal for the rest of the country, but on the other hand the growing season extends well into late autumn. Drought is not an important factor, but exposure is considerable at higher elevations and often limits plantability, for whereas in sheltered situations the planting line reaches an elevation of 1,500 feet, it is limited to 1,000 feet in less favourable conditions.

The geology of the forest is complex. Ordovician slates and grits are

irregularly interspersed with intrusive rocks which for the most part are felsite but sometimes more basic dolerites.

In the plantable area, soils vary from sandy loam to clay, the bulk being reddish-brown loam. Except on bare ridges and escarpments the soil is reasonably deep, even amongst bare rock numerous fissures provide soil pockets. On the plateau, peat is general and may consist of anything from a thin layer of peaty loam through all stages to many feet of fibrous peat wherever slight depressions are found at the higher altitudes. The plateau soils approximate to clays, are very fine in texture and, under the influence of heavy rainfall and poor drainage, have become consolidated and sour. There is some leaching of the soil but very little podzolization and no pan. On the upper and more gentle slopes, the soil is mostly derived from felsitic intrusives; these show some podzolization, a tendency to pan, and are distinctly acid. The soils derived from the dolerites are mainly clayey, and are very similar to those derived from the stratified rocks. On the steep slopes of the valleys, the loam is bright yellowish-brown, deep and friable, which, however, frequently becomes pasty by the action of outcropping springs. In a few instances, the valley bottoms carry a stiff alluvial clay.

Much of the vegetation as we find it to-day is the unnatural result of treatment and utilization. Probably the only natural types are bracken on the lower slopes and a *Molinia-Juncus-Scirpus*-Moss association on the deep peats. Most of the land has until recently been grazed by sheep, and this has resulted in the dominance of grasses on the lower plateaux, mainly *Nardus* with patches of *Juncus* and bracken, whilst on the upper plateaux *Molinia* and *Calluna* begin to come in on the sedimentary rocks and the latter is dominant on the more acid soils. When sheep are excluded, the upper plateaux undergo a complete transformation; the grass areas become dominantly *Calluna*, whereas on the more acid soils gorse comes in rapidly to give a dense gorse-heather mixture which so far has proved difficult to afforest. On the valley slopes also, gorse comes in where the soil is derived from volcanic rocks; in this instance it becomes almost pure gorse or a gorse-grass mixture, and tree growth is obtainable provided sufficient weeding is done. There are no natural tree associations, much of the old woodland was oak cultivated as coppice for bark. For the most part only remnants exist, and these occur on the valley slopes or at the lowest and most sheltered portions of the plateaux. In addition to oak one finds birch, sallow, dogwood, and mountain ash, but this again has been subject to grazing by sheep.

### AFFORESTATION.

The ground readily resolves itself into dry slopes and wet flats, and the technique of planting operations varies accordingly. On the dry slopes at lower elevations, practically the only areas needing special preparation are the old woodlands. Until three years or so ago, these were clear felled and replanted, a process which often led to the incursion of dense gorse or dense growth of coppice and natural hardwoods with consequent heavy weeding.

Since that time, such trees as are suitable have been felled for fence stakes, &c., and the rest have been ringed, with better results at reduced cost. The upper dry slopes usually carry a thin soil with broken rock, and trees were formerly notched. The species chosen for such sites are the spruces, and under these conditions they undergo prolonged check, resulting in expensive grass weeding. To avoid this, turfing was tried, but the turf obtainable was only a thin one and losses were sustained, especially in a dry spring. Eventually hinge-turfing was adopted with success. This method consists in severing a turf about 18 inches square on three sides only so that when rolled down the slope its lower uncut side acts as a hinge. Contact with the ground which is thus preserved appears to prevent the turf from drying out and also renders it wind-fast. On all other dry slopes the most preparation required is the burning of bracken in advance of planting. Planting is done by notching.

In the early days notch-planting was also the method adopted on the flats. This has now been superseded by turfing, and the period of check has been reduced although not by any means entirely eliminated, especially when small plants are used. In the single factor of reduction of losses, turfing has been wholly justified. An area of heavy soil in a high rainfall will naturally require considerable drainage. In this instance the plateau is so broken up that water comes in as springs in all sorts of unexpected places, and in addition the dip of the rocks has caused the formation of many terraces with small and mainly shallow bogs. Thus drainage needs to be intensive. It consists of three systems: major and minor contour cut-off drains, leads for springs and water-courses, and a herring-bone system for the bogs and wetter areas. All are inter-connected, and to them may be added deepened turf drains cut contourwise as far as possible. At this forest no ploughing has been done; first results obtained at a neighbouring forest indicate that this method of preparation would be most beneficial on all ground where ploughing is practicable.

Although much of the old woodland was hardwood there were some good plantations of conifers being and about to be felled at the time of acquisition. These were all standing at elevations not exceeding 900 feet and were, therefore, not indicative of the possibilities of the whole area, but as indicators for the valley slopes they were valuable. The principal species were European larch, Scots pine, and Norway spruce; small quantities of Silver fir, Weymouth pine, and *Thuja plicata* were present in the older plantations, and the younger plantations included some Douglas fir. Growth varied considerably, but from measurements taken it was shown at the time of survey that good, sound timber of ripe age and large dimensions was produced by all three principal species. The quality class and volume per acre at 70 years were assessed as follows:

| *Species.* | *Quality class.* | *Volume per acre.* |
|---|---|---|
| Norway spruce . | 60/70 ft. | 7,400 cu. ft. |
| European larch . | 50/60 „ | 3,700 „ „ |
| Scots pine . . | 40/50 „ | 3,900 „ „ |

Evidence of Douglas fir production was confined to young plantations 10 years of age, one of which then had an average height of 16 feet, and another, described as exposed, averaged 15 feet, which at that stage represented the 80 feet class giving a production of 6,900 cubic feet per acre at 70 years. In passing, other interesting details of height growth may be noted, such as Weymouth pine and Silver fir 100 to 110 feet at an approximate age of 90 years, and *Thuja plicata* 90 feet at 55 years of age. There was no evidence of the possibilities of Sitka spruce, Japanese larch or any of the more recently introduced exotics. From the information available, it was initially deduced that spruce would form some two-thirds of the crop, the balance being made up of Scots and Corsican pines, larch, and Douglas fir in about equal proportions. Land subsequently acquired contained a relatively higher proportion of upper plateaux, with the result that spruce still predominates.

Planting has now been in progress at this forest for 16 years and during that period 5,872 acres have been planted. The areas devoted to the main species are:

| | |
|---|---|
| Scots pine (including some mixture of pine and spruce) | 524 acres |
| European larch | 350 „ |
| Japanese larch | 783 „ |
| Douglas fir | 808 „ |
| Norway spruce | 1,257 „ |
| Sitka spruce | 1,677 „ |
| *Pinus contorta* | 38 „ |
| Subsidiary species, mixtures, &c. | 435 „ |

The general rules governing the choice of species may be stated briefly: Douglas fir on lower, sheltered slopes where the soil is firm. This species rocks badly in the wind if the slope is subject to springs and seepage water; consequently it is avoided on soft soils. Whether rocking is due to the soil itself or to type of plant used and method of planting is not certain, but until this point is cleared up Douglas fir is barred in such soils. This species is also chosen for old coppice and hardwood areas by reason of its ability to stand some shade and its habit of getting away quickly. European larch is used on lower slopes not actually wet, but unsuitable for Douglas fir, also on higher slopes and where conditions are rather harder than Douglas fir favours. Throughout North Wales, there are many plantations of this species thriving at a good age in conditions of this nature, but during recent years newly planted European larch has done indifferently in the wetter climates. Trees are irregular in their growth, readily attacked by *Adelges* (*Chermes*) and *Meria* when a few years old, and generally look sorry. Whatever the cause may be, and some suggest it is due to seed provenance factors, we now substitute Japanese larch in at least the wetter zones. Japanese larch also withstands more exposure than European, hence it is chosen for all sites where the latter has previously been planted and extends farther up the slope. At one time, this species was thought to be suitable for gorse ground, but that has not proved to be the case at Gwydyr, either in gorse-grass or gorse-heather associations.

Scots pine has so far proved to be the most successful species in gorse areas of both types. It is suggested that this is due to its ability to get away without check at a moderately rapid rate from the beginning, the formation of a tap root which makes it less dependent upon surface moisture than many other species, and its ability to grow in somewhat acid soil conditions. This species has also been chosen for the rockier and drier sites as well as in mixture with spruces in heather on soils derived from metamorphic rocks. Corsican pine was used as a wind-break until 1929, since when it has been abandoned, principally on account of the fear of fungus diseases in the wet climate. *Pinus contorta* has recently been used on shallow soils above terracing rock carrying a good deal of *Scirpus* amongst a dominantly heather vegetation, sites where any other species has so far been unsuccessful. *P. contorta* is promising, it gets away moderately well and does not yet show much tendency to blow. Norway and Sitka spruces are mainly used on the wetter land whether it be at low or high elevations or on the slopes. In the earlier years, Sitka spruce was planted at low elevations and Norway at higher altitudes. This order is now reversed, partly because Norway spruce suffers less from frost, and partly because Sitka spruce has proved the better starter in exposed situations. Experience has also shown that Sitka spruce is the better species on all soils carrying a vegetation containing *Scirpus*. On the other hand, Norway spruce appears to be the more successful in *Juncus* areas and on more or less pure *Molinia* ground. Hardwoods as timber producers have little place in conditions such as are found at Gwydyr, because, although considerable quantities of oak have been grown there in the past, the quality of the timber was inferior except upon specially favourable sites. The result is that to date only 30 acres have been planted with oak and it is unlikely that this area will be substantially increased.

The foregoing will have indicated that the object of management is the formation of a conifer forest. Planting technique, with the possible exceptions of Douglas fir areas, and the substitution of notching after ploughing in place of turfing, is well defined and has proved satisfactory. Weeding still presents some difficulty in two sets of conditions: old woodlands and grass areas. The partial clearance of the former combined with the ringing of the remaining trees has proved successful. But that is a recent innovation, and there are considerable areas which were clear felled and in these weeding is a problem. Formerly the method adopted was to weed until the newly planted trees had grown to the stage when their leaders were clear of other vegetation. This generally took 3 to 4 years and weeding then stopped. Subsequent development of crops treated in this way has shown that this does not appear to be sufficient because, firstly, undergrowth so checked catches up with the conifers within 2 years from the cessation of weeding and, secondly, natural hardwoods begin to come in at about the 4th or 5th year and grow very rapidly. Hence plantations treated in this way have almost invariably needed coppice weeding about the 7th or 8th year. This is an expensive operation, but unless it is done the crop may suffer heavily. Hence initial weeding is now prolonged for a further 2 years or so, which, although it does not altogether eliminate

coppice weeding at some later stage, has justified itself in the ultimate cost of weeding and the success of the crop.

It has been explained that a large proportion of the forest area is utilized as sheep farm prior to planting. When an area is enclosed and the sheep are removed, many sites produce an enormous crop of grass within 2 or 3 years of enclosure. Spruces are normally planted on such areas and undoubtedly are best able to withstand weed growth. Nevertheless, it has proved that weeding may be a vital necessity although it is a costly operation. Turfing has considerably reduced the necessity for weeding, but there is a tendency to use smaller plants on turves than in surface planting, and largely for this reason weeding still becomes necessary. The solution may lie in the adoption of larger turves and bigger plants. So far as gorse areas are concerned, all evidence points to the necessity for continuous hard weeding until the crop is above the maximum height to which the gorse may be expected to reach.

GROWTH.

Planting operations having been commenced 16 years ago, we are now beginning to see results. In addition to the main species mentioned, a host of subsidiary species has also been planted in groups or blocks of various sizes, and it will be interesting to include here a statement giving some representative samples of growth achieved under different conditions.

| *Species.* | *Elevation, feet.* | *Age, years.* | *Average height, feet.* | *Vegetation, soil, and notes.* |
|---|---|---|---|---|
| Sitka spruce (S.S.) | 500 | 17 | 40 | Planted prior to acquisition. At foot of old woodland slope, bracken and coppice. Deep soil with rock outcrops. Very vigorous. |
| Japanese larch (J.L.) | 700 | 16 | 33 | Conifers in pure blocks on old woodland site, deep soil, gorse, bracken, coppice, gorse at top of slope. J.L. is an even crop, D.F. attacked by *Adelges*, C.P. vigorous, not much reduced by gorse, E.L. useless in gorse, fair in coppice. |
| Douglas fir (D.F.) | ,, | ,, | 30 | |
| Corsican pine (C.P.) | ,, | ,, | 20 | |
| European larch (E.L.) | ,, | ,, | variable | |
| Beech (Be.) | ,, | ,, | 20 | |
| *Pinus ponderosa* | 200 | 16 | 20 | Old woodland, deep soil. |
| *P. insignis* | ,, | ,, | 35 | ,, ,, ,, ,, |
| *Sequoia sempervirens* | ,, | ,, | 30 | ,, ,, ,, ,, |
| Japanese larch | 700 | 15 | 25 | Old woodland, coppice, bracken and grass. |
| Norway spruce (N.S.) | ,, | ,, | 20 | Coppice, bracken, heather, gorse. 6–24 in. soil on broken rock. |
| Scots pine (S.P.) | 950 | 15 | 15 | Dense heather, some grass. Peaty soil on rock. |
| ,, ,, | ,, | ,, | 8 | Scrubby heather, some grass. Thin peat pockets on rock. |

| *Species.* | *Elevation, feet.* | *Age, years.* | *Average height, feet.* | *Vegetation, soil, and notes.* |
|---|---|---|---|---|
| Sitka spruce | 300–400 | 14 | 25 | Old woodland, deep soil, rock outcrops. Maximum height 35 ft., current shoot 24 in. |
| Japanese larch | 300–800 | ,, | 35 | Coppice ground at foot of slope. |
| ,, ,, | ,, | ,, | 6 to 18 | Rock to 18 in. loam on slope; heather and vaccinium. D.F. useless except in deep soil. |
| Douglas fir | 400 | 11 | 15 | Under thin crop of ringed oak. |
| ,, ,, | ,, | ,, | 13 | Open ground adjoining above. Both in coppice, gorse and heather. |
| European larch | 300–600 | 11 | 23 | Even crop. |
| Douglas fir | ,, | 10 | 20 | Oregon variety, *Adelges* attacked. |
| ,, ,, | ,, | ,, | 16 | Fraser River variety, very healthy. Larch and Douglas fir on deep soil, bracken and coppice. |
| *Abies grandis* | 200 | 10 | 10 | Irregular, healthy, vigorous. |
| *Abies nobilis* | ,, | ,, | 5 | ,, ,, ,, |
| *Tsuga heterophylla* | ,, | ,, | 7 | Irregular, wind blasted. |
| *Picea omorica* | ,, | ,, | 6 | Irregular, healthy. |
| Douglas fir | ,, | ,, | 15 | Attack by *Adelges*. All on thin soil, rock outcrops with deep pockets. Coppice and much dwarf gorse. |
| Japanese larch | 500–800 | 9 | 20 | Very regular. |
| Sitka spruce | ,, | ,, | 12 | Very uneven. Deep, old woodland soil. |
| Norway spruce | 200–300 | 8 | 3 | Vigorous on both types of land. |
| *Alnus oregona* | ,, | ,, | 18 | On moist sallow-alder-grass land. Vigorous. |
| ,, ,, | ,, | ,, | 6 | On *Molinia* land. Not vigorous. |
| ,, ,, | 100–200 | 7 | 25 | Old coppice, sheltered. Moist hollows |
| Douglas fir | ,, | ,, | 12 | with rock and dry slopes. |
| European larch | 600–1,000 | 7 | 6 | Very poor, doubtful as to final crop. |
| Japanese larch | ,, | ,, | 11 | Good but wind bent. |
| Douglas fir | ,, | ,, | 9 | Oregon. Vigorous but blasted. |
| ,, ,, | ,, | ,, | 4 | Fraser River. Poor and very wind damaged. |
| *Alnus oregona* | 650 | ,, | 12 | Somewhat blasted; at foot of slope. All on moist deep loam. Exposed. Grass and some bracken. |
| *Tsuga heterophylla* | 700–800 | 7 | 10 | Deep soil, grass, coppice, bracken, |
| *Abies grandis* | ,, | ,, | 4 | and brambles. Under ringed oak, |
| *Thuja plicata* | ,, | ,, | 3 | sheltered. *Tsuga* very good; *Thuja* very patchy. |

| *Species.* | *Elevation, feet.* | *Age, years.* | *Average height, feet.* | *Vegetation, soil, and notes.* |
|---|---|---|---|---|
| Scots pine | 900 | 7 | 3 | Heather, dwarf gorse; 2–6 in. peat on rock. Former even and bushy; latter very irregular and twisted in growth. |
| *Pinus contorta* | ,, | ,, | 3 | |
| Scots pine | 1000 | 6 | 2 | 6 in. peat on rock, short heather. S.P. mostly healthy; *P. peuke* less healthy; S.S. completely checked. |
| *P. peuke* | ,, | ,, | 1 | |
| Sitka spruce | ,, | ,, | — | |

Results up to the present enable us to draw the following conclusions so far as Gwydyr is concerned. Scots pine generally grows well, and is the most promising tree in gorse areas, even when heather is present and the soil is of the thinnest peat on rock. It is also the best tree on all rock outcrops where larch, Douglas fir, and spruce do no good. Corsican pine has been very little used. It is growing well on rocky ground where Japanese larch is poor and Douglas fir has died out. In another block, it is equally good in gorse and rock where European larch has failed, and on rock in severe exposure where Sitka spruce is badly checked. *Pinus contorta* is a recent introduction; it is the best species in one area of gorse-*Molinia* land. Otherwise it does not show to much advantage over Scots pine.

European larch is not nearly so successful as Japanese larch in height or regularity of growth. The latter does not appear likely to succeed as a timber producer on exposed areas as its bole bends readily. It is not a success in thin heather-peat ground and never looks at home in gorse of any kind. Douglas fir in the forest is apparently made up of a number of varieties, and results are very variable. Oregon strains take the lead early, but are later attacked by *Adelges cooleyi*, which causes a severe check to growth. Strains believed to be Fraser River start slowly, remain free from *Adelges* whilst Oregon strains alongside are attacked, increase considerably in rate of growth after a few years, and have so far retained a very good form. Of the spruces, Norway produces a much more even growth than Sitka although it is slower in starting. It also does better in areas carrying such vegetation as gorse-heather, pure dense *Molinia*, bog myrtle, and rushes. *Picea omorica* has only been tried on low-lying ground of good quality. Here it is very irregular and has suffered many failures, but once started it grows quite rapidly and looks healthy. *Abies grandis* seems to need a good soil and even then gets away irregularly. It grows rapidly and outstrips Douglas fir if the latter is attacked by *Adelges*. This species stands dense shade and a good deal of wind. *Abies nobilis* is a very slow starter. Its demands as to soil are not so exacting as with *Abies grandis*. It withstands dense weed growth, even gorse, quite well. *Thuja plicata* and *Cupressus Lawsoniana* are very promising at lower elevations and so far there is little to choose between them. *Alnus oregona* grows remarkably well on the lower, moist ground, but is less happy on *Molinia* ground and drier thinner soil. Other hardwoods are not out-

standing. Thinnings have just begun in Japanese larch planted 1921, but up to the present they have only taken the form of cleanings.

PROTECTION.

Insect and fungus pests are confined to *Adelges* on Douglas fir and European larch and sundry root fungi in old woodland areas. *Brunchorstia destruens* has not yet appeared on Corsican pine, an interesting fact in view of the rainfall.

As was to be expected in an old grazing area, the mountain sheep, which are such good jumpers, have given some trouble. The determined efforts of dispossessed sheep to return to their native heath continue for a few years, and even a seven-strand wire fence is insufficient to keep them out. The adoption of a sheep netting fence has done much to remedy the trouble.

Fire is an important consideration. The forest is intersected with good roads, a railway with steep gradients runs alongside the plantations for some distance in the Lledr valley, the forest lies in a big sheep-farming district, and it is a popular holiday and hiking centre. Fires have arisen from all these sources, and an extensive system of patrols is on duty during all dry periods. The most dangerous season of the year is the spring, the principal danger at that time arising from the railway and the local farmers. To guard against the former, a wide fire-trace is kept free from vegetation at the expense of the railway company concerned; also during a danger period all trains are met and followed by patrols who in the course of a season extinguish a large number of incipient fires; by these measures the reduction of the number of railway fires has been very encouraging. It has been the custom from time immemorial for hill sheep-farmers to burn grass each spring, consequently at times the forest may be virtually surrounded by a ring of burning mountain. Now the enclosure of grass land leads to the accumulation of dead grass, and when *Molinia* forms a considerable proportion of the grass species the plantations are very vulnerable. If a high wind is prevalent when conditions are dry, the risk is all the greater. For such hazards an adequate means of protection has not yet been discovered, and beyond ensuring wide distribution of gangs of fire-fighters for any emergency there appears to be little one can do until the farmers have sufficiently understood the risk involved and discontinue the practice of uncontrolled burning. For the rest, a system of fire-traces, patrols, organized methods of warnings and rapid transport of fire-fighters, coupled with gradual education of local inhabitants and visitors, have proved efficient in preserving the forest from serious outbreaks.

# CAIRNHILL PLANTATION, DURRIS

## AN EXAMPLE OF VARIATION IN THE RATE OF TREE-GROWTH RESULTING FROM DIFFERENCES IN SOIL

BY GEORGE K. FRASER

### INTRODUCTORY.

CAIRNHILL PLANTATION is a small block of some 15 acres in Durris Forest, Kincardineshire, the property of the Forestry Commission. It lies in the hollow between the three hills—the Craig of Affrusk, Cairnshee, and Northbrae, and is divided into two sections of unequal size by the road leading from the Bridge of Feugh, Banchory, via Tilquhillie to the Slug Road at Blairydryne. The rate of growth of the crop, chiefly Sitka spruce, is extremely uneven, because, while the tallest trees reach a height of over 50 feet, many are not more than 8 feet (Plate XV, Photo I and II). In this paper a record is made of the condition of the plantation as affording a striking example of the variation in rate of tree-growth frequently found on ground of irregular topography, and the conclusion is reached that this variation is the result of local differences in soil conditions, which can be recognized in the field, and which are associated with fairly definite differences in the ground herbage.

### GENERAL SITE CONDITIONS.

The plantation covers part of a flattish hollow near the outflow lip of the Northbrae–Affrusk Valley at a short distance from the steeper slope of the Dee Valley proper. The elevation is about 450 feet, and the area is not strongly exposed, being surrounded by higher ground except for small sectors to the south-east and north-west; the aspect is north-westerly. From the north and west borders of the plantation, good off-run is provided by the channels of the march burn and tributary ditches, while the surrounding cultivated fields ensure a certain degree of freedom from surface drainage from the higher ground near by. Within the plantation, there is a general fall from south-east to north-west, and a more definite slope from the road towards the upper part of the march burn. The south-eastern part (below B.M. 452·7 on Sketch-map I) is rather flat, but except for this the slope is sufficient to give moderately good surface drainage, with a steep cutting at the march burn itself. Underground water rises to the surface as two springs, marked $W_1$ and $W_2$ on the map, showing that the ground-water level is rather high.

The ground rock of the area is one of those impure limestones which are frequent in the metamorphics of the Dee Valley, and which vary from schistose limestones to calcareous schists or grits. In itself, it is here of little direct importance because it is well covered by drift deposits derived from granites and metamorphics; indirectly the calcareous ground rock is of some conse-

quence, since it determines to some degree the character of the ground water and even of the local drift which covers it. This glacial till does not differ much in appearance from the ordinary till of Deeside in general, but seems to have a higher silt-clay content than is usual, a condition which may be connected with the weathering out of the ground-down limestone taken up from the local rock. At the north-east corner of the plantation this till has been washed out and replaced to a considerable extent by alluvial sand which also spreads as a thin covering over the till into the plantation in the vicinity of the march burn at this part.

## EARLIER HISTORY OF THE AREA.

Certain information regarding the past treatment of the plantation since 1848 has been obtained from the Durris Estate 'Register of Plantations'; no exact information prior to this is available. However, in the Ordnance Survey Map of 1863–4 the area is marked as broad-leaved woodland. It is, of course, impossible to be certain as to species, but at the north point, on the south-east roadside and in the neighbourhood, there are ash trees which are quite likely relict or spontaneously derived from this earlier woodland. Natural ash is not unexpected in view of the calcareous ground rock, and ash is frequent on the lower slopes of the Dee Valley near by. In the plantation itself oak stumps of some size can be recognized; these are also considered to be remains from this natural woodland. It is therefore concluded from such evidence and from examination of scrub and woodland in the same type of locality that this natural woodland consisted chiefly of oak and birch with local alder and ash. Since very old Scots pine stumps are also found in the plantation, and since self-sown pines of considerable age grow on the sandy bank of the march burn, it is also likely that on the drier central area Scots pine was mixed with oak and birch.

This more or less natural wood was replaced in 1848 by conifers, the species being, according to the Register, 'fir, a few larch and spruce'. In 1899 this crop was removed, in 1900–1 the ground was ditched, but replanting was delayed until 1909–10. The planting consisted of Sitka spruce at 6 feet × 6 feet filled up with Norway spruce to 3 feet × 3 feet, but larch was used for this purpose 'on the better soil at the north end of the plantation'. A 'wind-mantle' of beech was planted along the south and west sides. The planting was held to have been successful, and no beating up was required. From that time until 1934 the plantation had apparently received no attention.

Since the year 1848 the ground herbage must have undergone a series of alterations in detail, but the first conifer crop consisting of 'fir with a few larch and spruce' is not likely to have produced changes in ground herbage which would not have been reversed, at least in part, by the 10 years fallow from 1899 to 1910. As is shown later, the impression of the vegetation of this period can be observed now even under the close canopy of Sitka spruce, and where tree-growth is poor the vegetation is scarcely affected by the crop at all.

PRESENT CONDITIONS.

1. *Soil Types.*

There are at least four major soil types within the plantation, with in addition a few local variations from these main types. These main types are:

I. *Calluna*-heath podzol with a gleyed subsoil, developed on boulder till.

II. Flush gley-soil characterized by the action of running stream- and spring-water.

III. Leached gley-soil developing under the influence of percolating surface drainage on a podzolized profile.

IV. Sandy alluvium without a definite profile structure.

I. The soil profile normally developed on undisturbed glacial till consists of these horizons:

$A_0$: a few centimetres of dark brown *Calluna* humus (mor).

$A_2$: about 5 cm. of leached grey quartz powder with a slightly brown tint below and changing without pan to B.

B: an ochreous yellow subsoil in which there are plentiful bright rusty and grey-green mottlings and streaks.

C: at about 60 cm. B has altered gradually to the greenish-grey, compact till.

This structure is typical of many of our rather wet *Calluna* heaths, but at Cairnhill the $A_2$ horizon seems abnormally plastic and the B horizon is rather more friable than is usual in purely acidic boulder till. Variations from this typical soil consist of (*a*) a greater depth of turf (peat-like) frequently along with a greater depth of leached mineral soil; this is confined to small patches, usually depressions; (*b*) a definite development of peat with deeply gleyed mineral soil, on flatter ground; (*c*) a more normal dry heath podzol of the bracken-heath type on the northern margin of the plantation, especially where the till is overlaid by a bed of alluvial sand; in this type the mor is mixed with the leached mineral soil forming a well-marked $A_1$ horizon, the B horizon is not strongly mottled and is tinted darker by humus; (*d*) a profile disturbed by erosion. On the steeper slope which borders the cutting of the march burn, the profile is of a type found on shallow soil on steeper hill-slopes. While the A horizon is variable owing to erosion, the B horizon is fairly consistent in having a brown-black upper section shading to bright rusty brown and to yellow below. At least in summer, this is a dry soil since it is shallow and much mixed with boulders.

II. Where the soil is irrigated by water from springs or has been subject to flooding by streams the profile is quite different, being as follows:

$A_0$–$A_1$: a variable depth (2–12 cm.) of amorphous humus mixed with mineral particles.

G: a considerable depth (up to 150 cm.) of grey-green mineral soil sometimes partly alluvial, sometimes showing prominent rusty mottlings at the surface or more frequently at lower depths, and changing rather abruptly into

C: the boulder till.

Between types I and II there are intermediate forms showing combinations of intermediate kinds of humus, of intermediate depths of grey surface soil, and of more strongly gleyed B horizon in type I. These intermediate forms cover a considerable area of the ground.

III. Although this type might be considered intermediate between I and II, it is described separately because of its distinct origin and general importance. It might be described as a secondarily waterlogged podzol. This type is usually included among podzolized soils, but for present purposes it is best considered as a waterlogged soil. It is found on the sloping ground of the western section of the plantation, which acts as a diffuse drainage slope for water collecting on the flat ground on the south-eastern portion of the section where a small peat deposit is forming. This type is very frequent on hill slopes over which peaty or acid water filters in diffuse runlets.

The profile at Cairnhill is as follows:

$A_0$: 5–7 cm.: turf, black and semi-amorphous, somewhat granular when dry, local patches of olive-green raw-humus.

A–G: 15–60 cm. of leached pale bluish-grey mineral soil, resting on

B: a red-brown zone of sesquioxide deposition, or on

C: boulder till.

B may be absent and where present may be considered to be part of the B horizon of an earlier podzol profile. Pan has not been observed at Cairnhill, but local iron crustations are found at the junction of the grey zone with the brown soil below it.

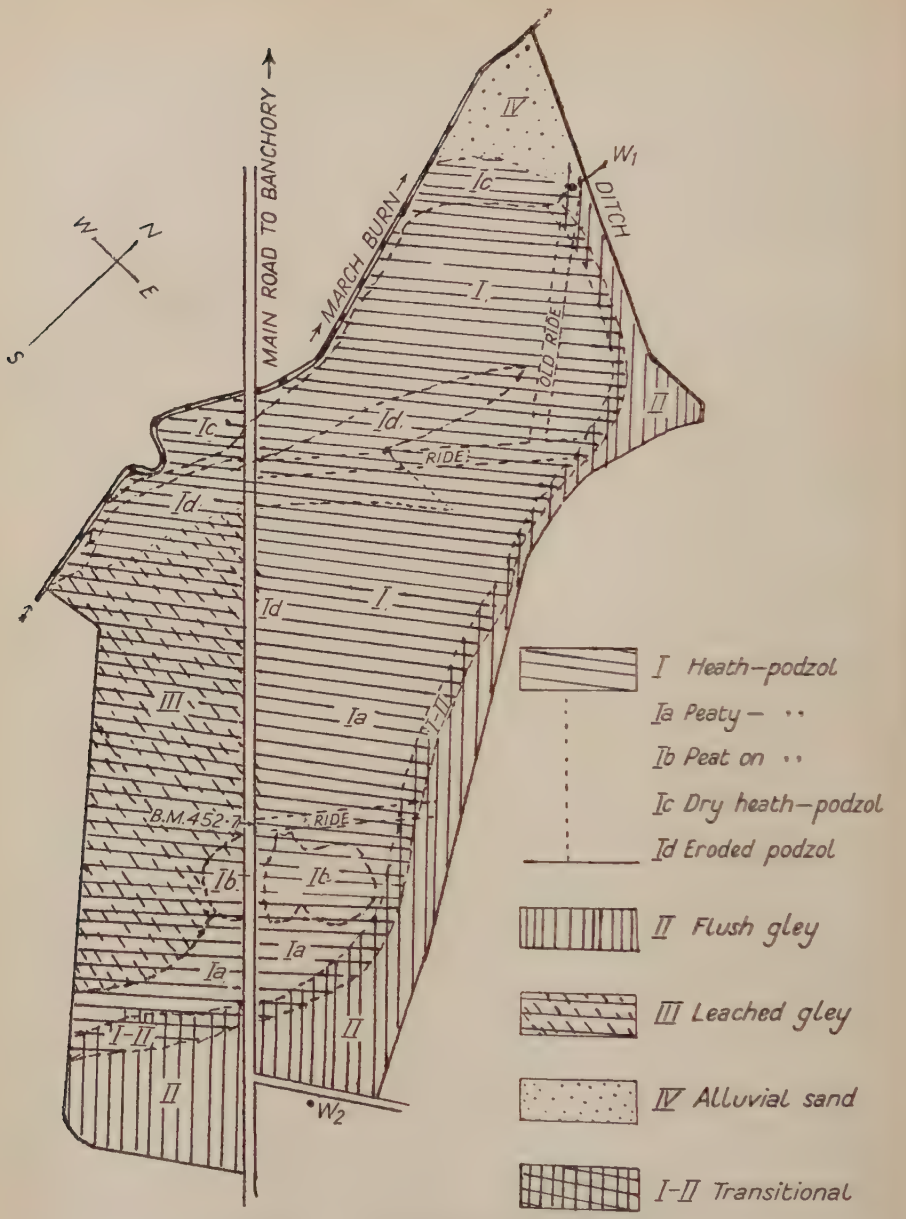
IV. Sandy alluvium without any definite profile structure is found locally at the northern point of the plantation. The absence of profile is partly due to the intense activities of rabbits, since conifer needles may be found mixed into the surface foot of soil almost at any spot. Here and there, however, there is evidence of the commencement of podzolization, so that this sand deposit is recent. Similar sand washed over the till at a higher level is definitely leached to an $A_2$ horizon but had been deposited at an earlier time. The distribution of these soil types is shown on Sketch-map I.

### 2. *Vegetation, its Present Condition.*

Ground vegetation is practically absent where the crop has been successful, but its former condition is not difficult to reconstruct in a general way from the remains of the more woody plants which are still recognizable and from external evidence. Corresponding to the soil types there are four main types, of which the third may be considered as an intermediate variety between I and II. The distribution of these types is shown on Sketch-map II.

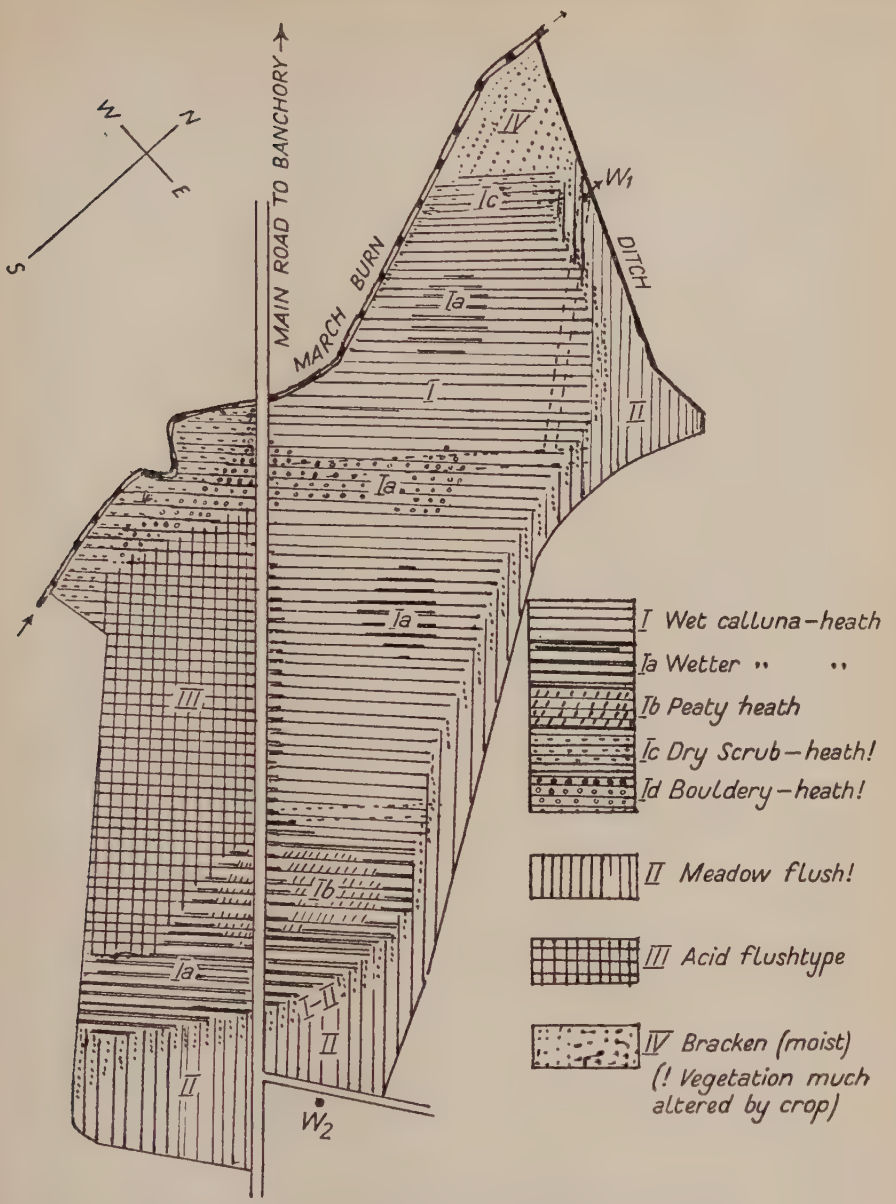
I. The vegetation of the podzolized soil is a wet *Calluna*-heath type, the chief constituents of which are:

*Calluna vulgaris*—abundant and dominant.
*Deschampsia flexuosa*—frequent, locally abundant.
*Erica Tetralix*—frequent, locally abundant.




Sketch-Map I. Soil map of Cairnhill plantation.

*E. cinerea*—common, locally abundant.
*Potentilla erecta*—common.
*Hypnum cupressiforme*—abundant.
*H. Schreberi*—frequent–abundant.
*H. crista-castrensis*—locally common.




Sketch-map II. Vegetation map of Cairnhill plantation.

*Hylocomium splendens*—frequent–abundant.
*Polytrichum commune*—frequent; locally abundant.
*Sphagna Acutifolia*—locally abundant.

This group of plants is typical of the moister parts of heath ground on Deeside. Variations in facies can be readily recognized: (*a*) on peat podzol where the ground is definitely wetter, *Sphagnum* and *Polytrichum* are more

abundant and *Erica Tetralix* is more frequent amongst the *Calluna*. (*b*) Where there is a definite peat cover the ground vegetation is less vigorous, *Calluna* is unhealthy, *Erica Tetralix* more abundant, and *Sphagnum* and *Hypnum Schreberi* are the chief mosses. Remains of cotton-grasses could be recognized in the peat though not found in growth. The vegetation is sometimes much disturbed here by grazing animals, possibly on account of the shelter offered by the surrounding trees. (*c*) On the drier type of podzolized soil vegetation is almost lacking. The remains still to be found on the floor of the wood show considerable variety. Where it borders on type I the herbage seems to have been chiefly *Calluna*, but within the sub-type, remains of birch, *Rubus*, *Ulex*, *Rosa sp.*, and bracken can be recognized. (*d*) Canopy is sufficiently close to suppress ground vegetation on some of the eroded podzol soil (I *d*). The chief plant remains noted are tufts of heather and pads of *Deschampsia flexuosa*. Where the ride crosses this type on the eastern side of the plantation *Calluna* is markedly compact and vigorous, *Erica Tetralix* forms definite clumps with abundant flowers, *D. flexuosa* is more abundant than in typical heath cover, but otherwise the vegetation is not remarkably different from that of parts of type I proper, i.e. the moist heath type.

II. The irrigated flush has no ground vegetation where planted up, but an overshaded ride at the north of the plantation and the roadside herbage at the south end afford indications of its earlier condition. At one or both of these localities are found *Ranunculus repens*, *R. flammula*, *Viola palustris*, *V. riviniana*, *Cnicus palustris*, *Juncus articulatus*, *Equisetum arvense*, *Holcus lanatus*, and *Deschampsia caespitosa*, all of which are usually found on marshy or fresh wet ground. On the ride the mosses are *Thujidium tamarascinum* and *Minium undulatum*. Below the dense growth of spruce, recent remains of oak, ash, willow (*S. capraea*?) were identified. The vegetation was therefore what one might expect on fresh humose flush, and, with the exception of ash, all the plants listed are found on flush on similar ground just outside of the plantation.

The transitional vegetation between this type and the *Calluna* heath type (I) can be recognized on much of the intermediate soils. The crop is often not so dense, and even below the denser spruce *Calluna* remains can be readily recognized. From these the conclusion is reached that the last interval between felling and replanting was long enough to permit *Calluna* to invade much of the intermediate ground so that *Calluna* tufts, usually open spaced, are common on soil which has an amorphous surface or sub-surface humus, which shows a grey gley-podzol surface mineral soil and strongly gleyed subsoil, i.e. on soil of a transitional type. The mixed character of the vegetation is indicated by frequent rowan, bramble, gorse, and *Polytrichum commune* remains. This condition of the surface herbage corresponds to what is frequently to be seen after clearing birch, or birch and pine, on moist sites; after some time *Calluna* invades the better soil in clumps, ultimately displacing the better herbage and forming a definite line of demarcation between strongly flushed and weakly flushed ground.

To the north of the plantation, nearby the more sandy podzol soil (I *c*),

gorse and bramble remains are quite frequent, but other remains could not be recognized in the field. Although the humus is very like that found on dry bracken ground, bracken remains were not recognized, but on a similar site just outside of the plantation gorse and bracken are the chief plants.

III. The vegetation now occurring on soil type III is scanty, irregular, and to a considerable extent casual, so that no definite picture can be formed of the whole. Most of the plants recorded are found only locally and many are grasses and agricultural weeds carried in from neighbouring fields. Rabbit grazing is very intense, as is shown by the close cropping of the grass around the edge of the plantation. Here, also, more than elsewhere, ditching might be expected to have produced unstable ground conditions. Relics of the earlier vegetation include *Calluna* (chiefly dead tufts), *Juncus*, *Tormentilla*; on a rough road which runs through the lower end of the slope occur flush plants including *Ajuga reptans*, *Cnicus palustris*, as well as *Holcus mollis*, *Anthoxanthum odoratum*, and some agricultural grasses. Among mosses the abundance of *Thujidium tamarascinum*, *Mnium* spp., and *Bryum* spp., also point to the wet fresh character of the surface soil.

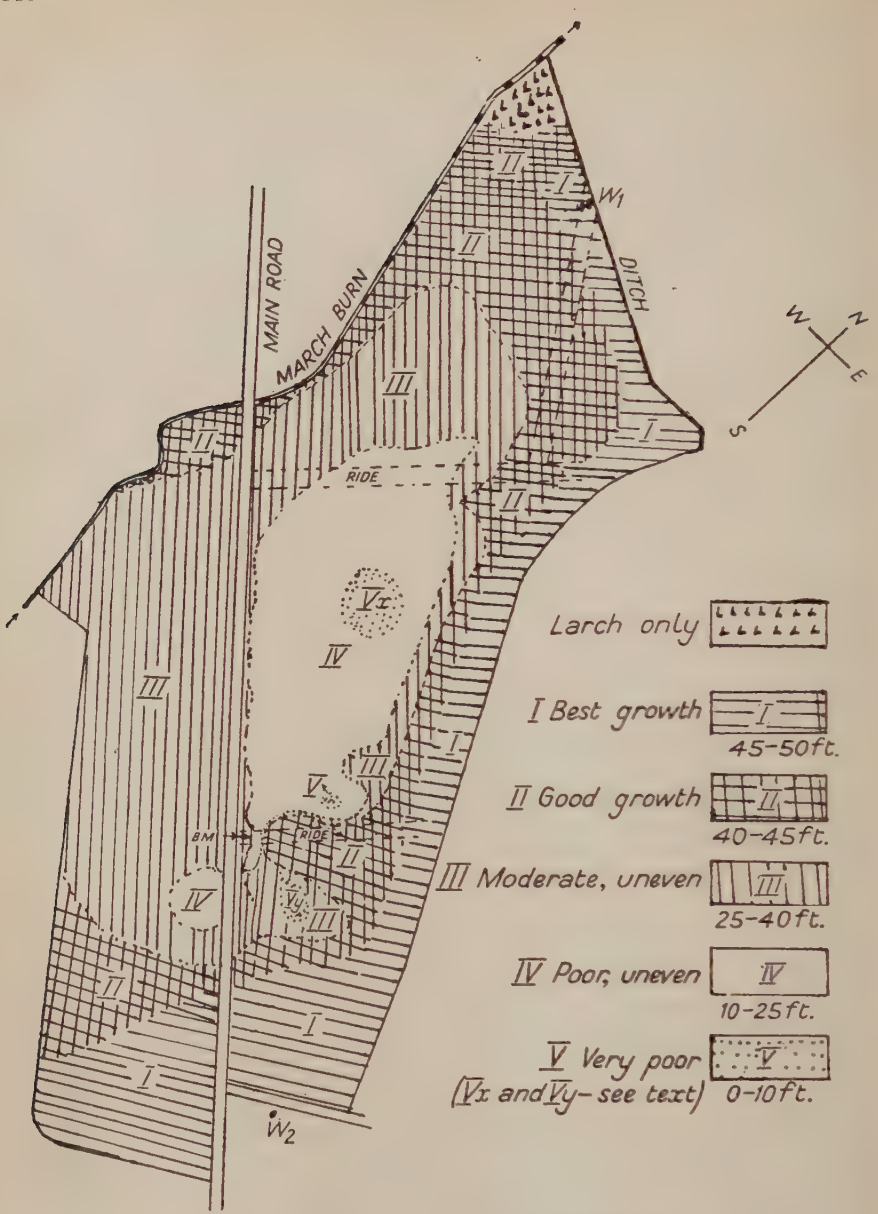
IV. On the sandy alluvium, grazing and burrowing by rabbits, even more than the shade of the crop, prevents the growth of ground herbage, so that only the deep-rhizomed *Equisetum* occurs sparsely. Before planting, the ground may have carried bracken, but no direct evidence of this has been observed. On a small patch beyond the influence of the crop and somewhat nearer the stream level, the herbage is chiefly *Holcus* and *Agrostis* spp. and *Anthoxanthum*, and on the opposite side of the stream on similar but drier ground bracken is dominant. It is considered from external evidence that this was most likely a moist bracken type with an undergrowth of grasses such as those mentioned above.

### 3. *The Growth of the Crop.*

The general distribution of crop quality is shown on sketch-map III. The boundaries are sketched in on the field and are not intended to afford more than a generalized view. For convenience of presentation the crop has been graded into five categories of growth as judged by ocular estimation. Within these boundaries and categories, however, accurate measurements have been made of selected plots and trees. For most of these I have to express thanks to Dr. Steven and to Mr. Allan of the Forestry Commission Staff who carried out the work.

The grades used may be shortly indicated as follows:

| | |
|---|---|
| I. Best growth . . . . . | height 45–50 feet. |
| II. Good growth . . . . . | height 40–45 feet. |
| III. Moderately good but uneven growth | height 25–40 feet. |
| IV. Poor and uneven growth . . | height up to 25 feet but chiefly less. |
| V. Very poor growth in patches . . | height below 10 feet. |




Sketch-map III. Crop map of Cairnhill plantation.

*Grade I.* The best part of the crop comprises a considerable proportion of the wetter and flatter ground to the south-east end of the plantation, and extends as a narrow strip along the whole eastern margin to the position $W_2$, where it again becomes broader. The largest trees are found at the south end of this area, where a height of over 50 feet and girth of 40 inches are reached.

Within the whole area sample plots give average heights of over 45 to 49 feet. This area of maximum growth lies upon the area of flush gley soil (soil II) and nowhere extends beyond it. On the transitional soil the crop is almost but not quite so good, for example, on the widest plot of this transitional type with *Calluna* remains on the floor the crop is very even with an average height of

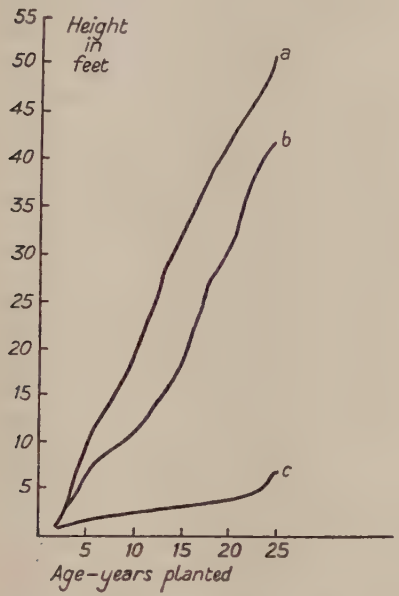



FIG. 1. Height-increment graphs of Sitka spruce (towards south-east of plantation). *a*. On Flush Type = Soil II. *b*. Transitional = Soil II–I. *c*. On Heath podzol = Soil I.

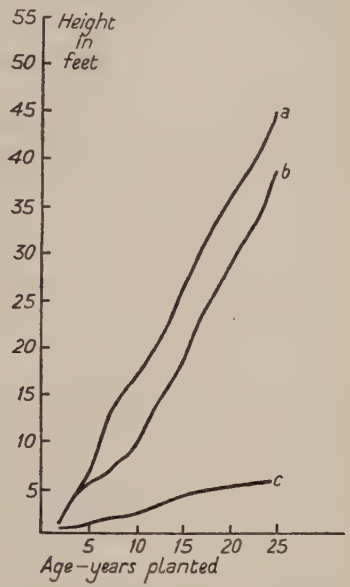



FIG. 2. Height-increment graphs of Sitka spruce (towards north-east of plantation). (*a*, *b*, and *c*, as in Fig. 1.)

45 feet, while on the flush itself near by the height is 48 feet. (Plate XVI, Photo 3.)

*Grade II.* The transitional zone is, however, so narrow as a rule that average heights can scarcely be taken and a better idea of the difference is given by comparison of the height increment curves of neighbouring trees, one on flush and one on transitional soil. Two representative examples of these are given from the south-east and north-east sides respectively in Figs. 1 and 2, which also includes a growth curve from the heath podzol, to be referred to later.

From the curve it is apparent that any difference in growth is essentially the result of check in the early years. As is commonly experienced, this check is no doubt due to heather on the transitional ground, and thus when the heather is killed out by the closing canopy, growth is quite as satisfactory as on the flush proper. A similar height is reached by Sitka spruce on the sand-covered podzol (soil I *c*). The remains of vegetation found here indicate semi-scrub conditions.

It is a general feature of spruce plantings that on heathy ground the rate of growth is much better where the plants are growing up with bushes or scrub than it is on the open heath vegetation such as *Calluna* or wiry grasses. Even individual plants of gorse, broom, roses, or juniper have a considerable effect in this respect. Such isolated examples are to be found in this plantation. Along the roadside, individual trees of much better growth are definitely associated with clumps or bushes of gorse or roses. In an unpublished piece of research work from the Macaulay Institute, M. M. Burns has found that no major soil difference is necessarily involved in this phenomenon, and therefore it seems that the benefit received by the tree is reduced to two factors: (1) shelter, and (2) reduction of root competition with the ground cover-plants which are shaded out by the shrub layer. Thus initial check to tree growth is much reduced. On soil type I *c* there can be no doubt that this factor has had great importance in promoting the growth of the crop, while the soil itself is definitely of a better type than the normal wet-heath podzol (I).

*Grade III.* In this grade have been included areas with growth ranging from just over 30 feet up to just below 40 feet, and these show a similar irregularity in growth from individual to individual. This is in part a natural feature of the stage of height growth reached (i.e. the dominant stems are breaking away), but is not chiefly due to this but to individual differences in the period and intensity of check. The grade covers, in addition to the greater part of the western section of the plantation, central patches to the north and south of the eastern section as well as narrower strips elsewhere. The causes for this unevenness are not constant over all. In the northern patch this type represents the gradual improvement of growth following the protection of surrounding well-grown trees. Here this effect is intensified by the presence of numerous spontaneous larch and Scots pine, which act in a manner similar to the shrubs already mentioned. (Plate XV, Photo 5, shows the effect of larch in this respect on an area of poor growth.) Here the average height of the crop is 36 feet (or perhaps higher), and blanks occur, an indication of the initial slow growth. To the south of the eastern section the crop is similar in character and is similarly protected by good trees, but here irregularity is due in part to variations in surface soil, peaty patches and wet hollows occur, and on some of these there are blanks. (Plate XV, Photo 6.) There is little difference in average growth between the crop on this type of ground and that on soil type I *d* on the bouldery slope chiefly on the western section near the march burn. Irregularity in growth is here to be expected from the local differences in a washed bouldery soil already described. The mean height is less than was expected from the size of some individual stems.

The greatest area of this grade covers the waterlogged podzol soil type (III). Plate XVI, Photo 4, was taken on this type after the crop was thinned. The average height is from 32 to 35 feet, while individual trees range from 15 to 38 feet, canopy is closed throughout, and larger and smaller trees grow in close proximity to each other. Such differences are obviously the result of minor factors like individuality of the plants or minor differences in surface soil such

as are frequently found where temporary surface flushing occurs on heath and peat, and are often accentuated by drainage or by mixed vegetation such as *Calluna* developing on drier parts, grasses on wetter parts of a flush. In addition, larch was used extensively here to 'fill up' the Sitka spruce crop in place of Norway spruce.

Figs. 3 and 4 illustrate the mode of growth of plants under these conditions. Where the growth of two plants of different sizes standing on the same soil

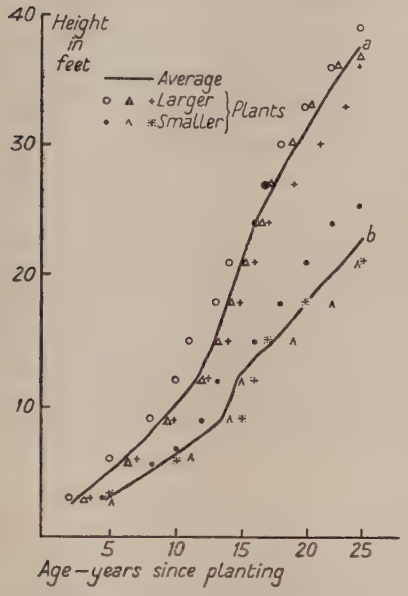



Fig. 3. Height-increment graphs of three larger Sitka plants, (*a*), compared with three smaller adjacent plants, (*b*).

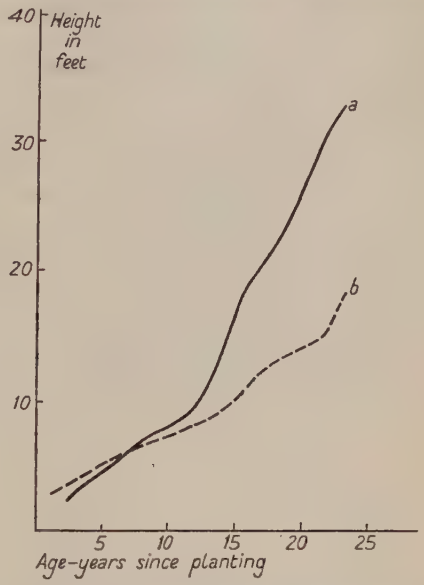



Fig. 4. Height-increment graphs of a Sitka not shaded by larch, (*a*), and of an adjacent plant, (*b*), overshaded by larch.

and close to each other is graphed (Fig. 3), it is found that the growth of the smaller plants has been lower throughout as compared with the better plants; i.e. the difference is the result of a local site factor from which the plant has not yet recovered, or is due to inherent differences in the two individuals. On the other hand, as shown by Fig. 4, a plant growing along with closely planted larch begins its growth at the same rate as its unshaded neighbour, but when larch canopy becomes dense at the age of 7–10 years, a definite reduction in the rate of growth takes place and this becomes proportionally greater so long as larch forms an over-canopy. In the 'Record of Plantations' no reference is made to the planting of pure larch on the sandy alluvium (IV) at the north end of the plantation. It may, therefore, be assumed that here also a mixture of larch and Sitka spruce was used. This is now a patch of pure larch. It seems likely, therefore, that this overshading process has here gone a stage further, and that the Sitka spruce did not get away on this site, under shade of the rapidly growing larch (40 feet as compared with 30 feet in the western section). Comparison of the beneficial effect of the occasional spontaneous larch on poor

ground with the harmful effect of closely planted larch may throw some light on the use and control of mixtures in the formation of plantations.

*Grade IV*. On the greater part of the podzolized heath soil the rate of growth is definitely poor. The average height is estimated at 8–12 feet, but individual variation is wide, from 2 feet to 20 feet. In addition there are, locally, individual trees and groups of trees of distinctly better appearance where no change of soil can be detected. Some of these have been referred to earlier, for example, where associated with gorse, spontaneous larch (Plate XV, Photo 5), or Scots pine. (If these special cases be included in this category then the maximum height reaches 30 feet or thereabouts.) Similarly the drop in height of the crop from good growth to poor growth does not correspond exactly with the change in soil, but growth is improved on the poor soil by the sheltering effect of the adjacent taller trees. It is therefore concluded that it is a matter of time before the ground as a whole is covered by close woodland. At present, however, it is impossible to determine in the field the causes of the variation which exists from plant to plant, although it is no doubt in part a consequence of minor differences in the ground surface, drainage, &c.

*Grade V*. Some patches of moderate size within the heath type show very poor growth, being comparable with the poorest specimens occurring throughout the type. Here it is usually possible to find a reason for failure in poorer soil conditions, indicated by greater or lesser change in vegetation, such as deeper turf, bad off-run with peaty turf and such like. But it is not always possible to find soil differences. For example, at site *X* on Sketch-map III, the vegetation and soil are to all appearance the same as on the surrounding ground, and here continued check is due to the central position of the patch—it is least under the influence of the taller trees. On the other hand, at *Y* there is a very poor patch even although it is well sheltered; here peaty turf and bad aeration resulting from bad off-run constitute the major factors causing check (Plate XV, Photo 6). The ultimate success of trees surviving at *Y* is much more uncertain than of those at *X*. For comparison, growth curves of two of the poorer trees have been included in Figs. 1 and 2, but call for no further mention. Cross-sections of the stems of these show injuries, such as false rings, usually associated with frost.

The poor growth of some groups and individual trees is due in part to grazing animals. The abundance of rabbits has already been referred to, but their effects have been on the whole indirect, such as grazing down shelter-growth of plants like rowan and birch. The 'wind mantle of beech' on the western side of the plantation is mostly dead, and even now survivors are being badly barked. In one patch Sitka spruce has been damaged by deer—probably roe-deer—but are now recovering.

## SUMMARY AND CONCLUSION.

The variations in the rate of growth of the crop in Cairnhill plantation, Durris, are associated with major differences in soil which are essentially topographical in origin. Growth of Sitka spruce is good on soil influenced by

PLATE XV

1. Looking across the eastern section of the plantation from the road. In the foreground the height of the crop is about 20 feet, in the centre falls to 3 feet, and in the background rises to more than 40 feet.

2. A closer view of the variation in height growth, from 3 feet in the centre of the foreground on Calluna Heath podzol, to over 40 feet in the background on flush soil, the intermediate trees growing on transitional soil conditions.

5. Trees of poor and uneven growth on Heath podzol soil (I). Those in the foreground are typical. Between and around the self-sown Scots pine and Larch in the background the Sitka is now beginning to show satisfactory growth.

6. Showing the failure of growth on a patch of waterlogged peat with dead heather, changing to flush soil and good growth in the background. Evidence of rabbit

PLATE XVI

3. Trees of the best quality after thinning. The best stem (on the left of the photo) is over 50 feet. On spring flush soil (Type II).

4. Trees of moderately good but uneven growth after thinning, height about 35 feet (graphed in text, fig. 3 (*a*). On waterlogged podzol soil (Type III).

irrigation with spring water especially where flushing has been the major factor in soil formation; where flushing is produced by surface action of water collecting on peaty soil, growth is not so good; on the typical moist *Calluna*-heath podzolic soil, growth is on the whole poor, but in some varieties of this is fairly good. Although the original vegetation of the plantation cannot be reconstructed with great detail, enough evidence, internal and external, is at hand to show that the soil differences were accompanied by fundamental differences in vegetation which could have served as a guide in the choice of species or in the estimation of mode of treatment and probable results. The rate of growth of Sitka spruce is here, as is usual for most trees, decidedly improved by the proximity of higher plants, especially during the earlier stages of growth—for example, plants such as gorse or spontaneous saplings. Thus improvement in growth on poorer ground follows the good growth of the crop on adjacent good ground, and it is to be expected that the whole crop will progressively close canopy in this way, a process which could have been hastened by mixing the crop with nurse species. On the other hand, the excessive shade produced by densely planted quick-growing larch has either killed out the Sitka (on open sandy soil) or has definitely hindered its growth, after canopy is closed, as on semi-flush soil less suited to the larch. Cairnhill plantation is thus a compact and interesting example of the kind of ground variation and type of problem which is usually met with in the afforestation of heath-covered hill country of irregular topography.

# THE INFLUENCE OF CERTAIN ACCESSORY FACTORS ON FROST INJURY TO FOREST TREES

BY W. R. DAY AND T. R. PEACE

## I. INTRODUCTION.

WHEN the results of the authors' experiments on the artificial production of frost injury on trees were published in 1934 (5) it was stated that 'Experiments on other factors, which may increase or decrease the injurious effect of low temperatures under natural conditions, have up to the present only been carried far enough to indicate that it is unlikely that they are either individually or collectively so important as to displace temperature from its position as the primary cause of damage.' Nevertheless, it was felt that these factors were of sufficient importance to warrant their further investigation, and during the years 1932 to 1936 experiments on them were carried out, and will be published in a short series of papers of which this is the first.

The factors considered are enumerated below. Most of them are dependent on the natural environment of the plant, with particular reference to the meteorological circumstances at the time of the frost, but many of them can be modified by human interference, particularly in the case of small plants, such as forest trees in the nursery.

*a. Temperature conditions before freezing.* By exposure to suitable, but not damagingly low, temperatures plants are rendered more resistant to frost; this is the process known as hardening, and takes place naturally during the autumn. Conversely, exposure to high temperatures when the plant is in a hardy condition may lessen its hardiness.

*b. The rapidity of freezing and thawing.* It is obvious that in nature these factors will vary according to the weather conditions preceding and following the frost, and according to the severity and duration of the frost itself. They vary according to the aspect chosen for the plantation, and can be modified both in the nursery and in the forest by sheltering.

*c. The duration of freezing.* It is obvious that the duration of frost and also the period during which the temperature is sufficiently low to cause damage varies very greatly in nature. This factor is not so easily modified as the previous ones.

*d. The repetition of freezing and thawing.* In nature frosty periods often occur when there are frosts for several nights in succession, but thaws during the intervening days.

*e. The time of day at which the frosts occur.* This is not of great importance in nature, since usually the lowest temperatures are experienced about dawn. But since experiments on other aspects of frost injury have been carried out regardless of the time of day, and since the metabolic activity and therefore the state of the cell contents of the plant does alter throughout each twenty-four hours, it was thought that this factor should be considered.

*f. Air movement and humidity.* The importance of cold winds is discussed below. Since evaporation is controlled not only by the humidity of the air, but also by its rate of movement, these two factors are best considered together. It is common practice to modify air movement in the forest and nursery by various forms of shelter.

*g. Dry or frozen soil, and defective root systems.* These factors are all connected with lack of water. The last is of considerable importance as it includes the effect of root damage during transplanting, and of the check in root absorption inevitably associated with this process on subsequent frost damage.

*h. Wetting the leaves before freezing.* This may happen in nature when rain precedes frost.

*i. Manuring the plants.* The chemical composition of the soil in so far as it affects that of the plant might be expected to have some influence on frost injury.

*j. Handling frozen plants.* It is well known that handling plant tissue while it is still frozen increases the injury to it. Since under certain circumstances it may be desirable to handle young trees during a period of prolonged frost, this matter is of some practical importance.

Before considering the experiments that have been carried out by the authors and others on the effect of these factors, and before attempting to explain why they behave as they do, it is necessary to have some understanding of the underlying causes of frost injury. Owing not only to the importance, but also to the complexities of this problem, a great deal of work has been done on it, which can only be discussed very briefly and incompletely here. Summaries of the work done up to their date of publication are given by a number of authors (24, 30, 31, 39, 46, 49, 52). From the forester's point of view it is unfortunate that so much of the work has been done on agricultural and horticultural crop plants, and that so much of it refers to fruit and so little to forest trees. For a clear understanding of our present knowledge of the mechanism of frost, much of the work on non-woody plants must perforce be mentioned, though it cannot be directly applied to forest trees.

It is still a matter of dispute as to how much of the damage to trees during cold periods in winter is due truly to frost, and how much to wind. The most usual explanation of the role of wind in this matter is that it causes excessive transpiration during periods when the soil is frozen and the intake of water negligible, or when the stem is still frozen and the upward movement of water impossible, while the more exposed leaves have thawed. In the case of spruce, for instance, Münch (33, 34) and Pfeiffer (38) are of the opinion that most of the winter damage to spruce in Saxony is due to low temperatures, whereas Schmidt (40) holds that in the Black Forest the damage is due to excessive transpiration, and states that, within the natural range of spruce there, the temperature never falls sufficiently low to damage them during the winter. The authors' experiments on spruce and other conifers (5) suggest that in this country, where, of course, the climate is very different to that of south Germany, damage during the winter by cold alone is quite possible; but it is only

reasonable to suppose that damage due to excessive water loss may also take place. This question of the importance of wind and frozen soil in winter damage, apart from the low temperature effects of frost, will be discussed later when these factors are considered. While the importance of low temperature in winter damage is uncertain, there is little doubt that it is responsible for practically all the so-called frost damage occurring in the autumn and spring. At these times any plant which is native of a temperate or arctic climate is much more susceptible to low temperatures than in the winter. Briefly, in this country at any rate, susceptibility is at its lowest in January; it rises throughout the spring, the rise being particularly rapid during the period when growth is starting, reaches its summer level at the end of May, and from September falls again to the hardy winter level. These observations are based on work on trees (5), and it is possible that the periods may vary somewhat for other plants.

It is thus important to understand what happens in the plant when it is subjected to low temperatures, what chemical and physico-chemical properties of the cell affect this, and how they act. The most usual method of approach to this problem has been to compare hardy and non-hardy plants, or more often hardy and non-hardy varieties of the same plant, and to determine in what manner they differ. Another approach is to find out what changes take place in the plant during the process of hardening, because these are likely to be associated with increased frost resistance. A brief review of this work is given below. Shutt (43), and Beach and Allen (2) working with apple twigs found that the moisture content of the hardy varieties was lower, as did Newton (35), Åkerman (1), Martin (28), and Dexter (6) for wheat. Langlet (23) recently found the same relation for races of Scots pine, and Schwechten (41) for fruit rootstocks. Pfeiffer (38) found that in winter the shade needles of Norway spruce were more frost susceptible and had a higher moisture content than the sun needles. On the other hand, Rosa (39) working with various vegetables stated that increased moisture content was associated with hardiness; while Hildreth (17) using apple twigs, and the authors during work on races of larch, failed to find any relation between moisture content and resistance to frost.

Another suggestion was that increased sugar content indicated increased hardiness (26), and this has been supported by the work of Maximov (30), and by that of Govorov (15) and Mudra (32) on cereals. There is no doubt that in the autumn the sugar content increases at the expense of starch in hardy plants and that the reverse process takes place in the spring. Tysdal (48) working on alfalfa has found that there is some correlation between hardiness and the activity of the diastatic enzymes, which are responsible for this change from starch to sugar. Tuttle (47) working to some extent on trees suggested that an increase of oil at the expense of starch was also associated with increased hardiness. In contradiction to much of the work above, Hildreth (17) working on apple trees and Lott (27) working on brambles failed to find any correlation between hardiness and sugar content.

The osmotic pressure, which is closely related to the concentration of soluble substances in the cell sap, has been considerably investigated. Ohlweiler (37), Korstian (22), and Levitt and Scarth (24) working on trees and shrubs found that high osmotic pressure was associated in a general way with resistance to frost, as did Åkerman (1) and Martin (28) working on wheat, Chandler (3) and Rosa (39) for a variety of vegetables and other plants, and Schwechten (41) for fruit rootstocks. Winkler (54), Lewis and Tuttle (25), Korstian (22), and Gail (14) all working to some extent on trees have found that osmotic pressure is highest in the winter. This supports the probability that it is associated with frost resistance; but the period of maximum osmotic pressure does not always coincide exactly with the period of highest frost resistance. Kessler (21), on the other hand, using various plants, including ivy, failed to find any relation between frost resistance and osmotic pressure. Since the effect of dissolved substances in water is to lower the freezing-point, high osmotic pressures are naturally associated with low freezing-points, and the lowering of the freezing-point should lessen the danger to the plant from frost. West and Edlefsen (53) working on twigs of fruit trees, and Wright and Taylor (55) using potatoes have found that the lowering of the freezing-point is associated with increased hardiness. But Harvey (16) using cabbage and tomato plants, and Steinmetz (45) and Weimer (51) using alfalfa have failed to find any connexion between them. In contradiction also to a good deal of the work mentioned above is that of Dexter (6) using wheat, who states that hardiness is accompanied by a low concentration of soluble salts.

The factor which has, perhaps, given the best correlation with frost resistance is 'bound water', that is, the water that is held by the colloids in the cell, and cannot be extracted by freezing. That an increase in bound water is associated with increased frost resistance has been found by Rosa (39) for various vegetables, by Martin (28) for wheat, by Holbert and Frye (18) for corn, by Novikov (36) for cereals and shrubs, by Kessler (21) for various plants including ivy, by Lott (27) for brambles, and by Levitt and Scarth (24) for various plants including trees. But Weimer (51) working on alfalfa, and Mayer (31) using *Pinus rigida* were unable to find any satisfactory relation with bound water. Since the power of the colloids to bind water must to some extent be dependent on the amount of water-holding or hydrophilic colloids present, a relation between the amount of these and frost resistance is to be expected. This has been found by Rosa (39) for various vegetables, by Newton (35) for wheat, by Dunn (11) for brussels sprouts and alfalfa, and by Dunn and Bakke (10, 12, 13) for apple trees, though in the last case it was unsatisfactory in some experiments. Working with pentosans alone, Hooker (19) using apple trees, and Rosa (39) various vegetables, found that a greater pentosan content indicated increased hardiness. But Hildreth (17) using apple trees, Lott (27) using brambles, and Doyle and Clinch (9) using conifers, failed to find any such relation. Recently Levitt and Scarth (24) have found a very good relation between increased permeability of the cell and increased frost resistance.

It is obvious from the above that frost resistance is associated with a large number of different cell constituents and cell conditions, but that in many cases the association is a very loose one, and may be apparent only under certain conditions, and that their relative importance varies in different kinds of plants. For instance, Levitt and Scarth (24), who found a good correlation between bound water and frost resistance in various trees, failed to find any bound water in cabbage, which is, nevertheless, a very hardy plant. It is known that these cell factors are markedly affected by the hardening process, and it is possible that some of the contradictory results quoted above may have been due to differences in the method and degree of hardening to which the plants were subjected. It remains to discuss why these cell factors are associated with frost resistance, and how they, and therefore frost resistance, are likely to be affected by the environmental factors which it is the main purpose of these papers to discuss.

We know that, when a plant is exposed to a temperature some degrees below freezing-point, ice is formed in the intercellular spaces (30, 50), and less commonly in the cell itself (24, 49); under certain circumstances it can be formed outside the plant; thus Dorsey (8) has described ice formation between the bud scales on peach trees. The primary reason for the failure of ice to form, until the temperature has fallen some degrees below the freezing-point of water, is the depression of that point by the soluble substances in the plant juices. The freezing-point of the sap is not usually very low; Dorsey (8) gives 27° F. for peach buds during the dormant season, Young (56) 26–28° F. for orange fruits, Lewis and Tuttle (25) 28° F. and 27° F. for begonia and lilac respectively, and Dixon and Joly (7) about 23–25° F. for yew. In the last two cases the time of year was not given. None of these, except yew, is a particularly hardy plant; but Lewis and Tuttle also give a remarkable freezing-point lowering of −35° F. for *Pyrola* leaves in a hardened condition. The point at which ice formation begins may be still further lowered by undercooling. If water is kept absolutely still, it is possible to lower its temperature below the freezing-point without ice formation; this is particularly the case if the water is confined in very narrow spaces such as capillary tubes, or, in the case of a plant, the intercellular spaces. When ice formation does start, however, it is very rapid and it is accompanied by a rise of temperature to the freezing-point of the sap. This undercooling often takes place in plants, and may enable them to undergo temperatures two or three degrees below the freezing-point of the cell sap without ice formation taking place. Young (56) states that oranges may sometimes be cooled below the freezing-point of their sap by 2–3° F., Lewis and Tuttle (25) produced undercooling ranging from 0·5 to 2° F. in a number of plants, Wright and Taylor (55) 4° F. in potatoes, and Dixon and Joly (7) 11° F. in *Taxus*. Naturally undercooling is only of benefit to the plant if the temperature rises again before ice formation has started; once this begins the effect on the plant is just as bad as if no undercooling had taken place, or, indeed, owing to the extremely rapid formation of ice, it may be worse. As ice formation takes place the concentration of the remaining cell sap rises,

and the lower, therefore, does its freezing-point become, because it is only the water, not the substances in it, that freezes.

Two main theories exist as to the effect of ice formation on the plant. The first holds that ice causes distortion and rupture of the plant tissues, and the second that the ice itself does little or no harm, but that the withdrawal of the water from the cell sap is the harmful factor, this acting by altering the colloidal structure of the cell sap in such a way that it cannot be reconstituted when thawing takes place. In addition it is certain that some plants can be damaged by low temperatures without ice formation. Sellschop and Salmon (42) report damage to a number of tropical and subtropical plants owing to exposure to temperatures near to but above freezing-point. Since this can occur there seems every reason to suspect that damage unassociated with ice formation may take place in more hardy plants at temperatures below freezing. These authors suggest that the injury is due to nutritional disturbances, possibly accompanied by the accumulation of toxic substances. But Sorauer (44), who damaged begonias by exposure to freezing temperatures for so short a period that ice formation was impossible, was of the opinion that the injury was due to sudden changes in the tension of the cell walls, and consequent structural damage. So little is known about this aspect of the matter that we can only consider the various chemical and physico-chemical factors, which, as we have seen above, are associated with frost resistance, in relation to their effect on ice formation and its consequences. The importance of the lowering of the freezing-point is obvious; increased sugar concentration and increased osmotic pressure are both associated with an increase in it, so that all these factors should normally have the same effect on hardiness. The importance of bound water may be either that it prevents a disturbance of the colloidal structure or merely that it lessens the amount of water that can be converted into ice and therefore lessens the total ice formation. The hydrophilic colloids which are responsible for holding this water will obviously be of equal importance. The relation of moisture content to frost resistance can be explained on a number of grounds. Low moisture content may indicate high osmotic pressure, and possibly also a high concentration of hydrophilic colloids; but naturally the more water the more ice, and it may act merely by affecting the amount of ice formed. Levitt and Scarth (24) explain their correlation of frost resistance with cell permeability by suggesting that the higher the permeability the more easily can water escape from the cell, and the less likely is ice formation to take place inside the cell, where it would do more damage than in the intercellular spaces; also that a good supply of water in the intercellular spaces may increase the rate of crystallization and on this account lessen the size of the ice crystals, which would therefore do less damage to the cell structure. In addition it is possible that the greater ease with which substances in solution in the cell sap could escape from the more permeable cell may influence injury by depressing the freezing-point of the solution in the intercellular spaces.

The experiments of Maximov (29) and Chandler and Hildreth (4), who found that freezing and thawing plant tissues in strong solutions lessened

damage, make it doubtful whether frost injury can be due to the increased concentration of the cell sap, consequent on the withdrawal of water to form ice, acting adversely on the colloids. For under these circumstances the concentration during freezing can hardly be less and may well be more than it would be naturally. These authors conclude, therefore, that damage is directly due to the effect of ice, which probably disrupts the cell membranes or damages the colloidal structure by its pressure; but Iljin (20), who found that thawing plant tissue in strong solutions lessened damage, asserts that this is due to their preventing the too sudden expansion of the protoplast, which becomes plasmolysed during freezing, and its consequent disruption and death.

It will be seen, therefore, that the mechanism of frost injury is as yet far from understood. It may be to some extent chemical, nutritional disturbance taking place, or toxic substances accumulating, during prolonged exposure to cold; it may be physico-chemical, the colloidal structure of the cell being damaged by too sudden alterations in the conditions under which it exists; or it may be physical and depend on the rupturing of the cell membranes and possibly of the cell walls by the mechanical action of ice. There seems every reason to suppose that the effect of low temperatures on the plant is a complex one, and in the opinion of the authors more than one of these methods of injury are likely to be concerned in frost damage to trees.

It can easily be seen how the environmental factors with which these papers are concerned might, by affecting the cell sap and its manner of freezing, increase or decrease the injurious effect of frost. For instance, the duration of the frost will not only increase the amount of ice formation if that takes place, but also affect the chances of the plant surviving the frost unfrozen owing to undercooling. The moisture content of the soil, by affecting the turgidity and, therefore, the osmotic pressure of the cell, might have some effect, or manuring by altering the cell contents. This will be discussed further when each environmental factor and the experiments on it are dealt with.

(*To be continued.*)

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# THE PRESENT STATUS OF THE DOUGLAS FIR WOOLLY APHIS (*ADELGES COOLEYI* GILLETTE) IN BRITAIN

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## INTRODUCTION.

DURING all the years that have elapsed since the so-called 'woolly aphis' of the Douglas fir was first recorded in 1913 on its secondary host in Britain, until the galls of the species were found on the primary host, Sitka spruce, at Peebles in 1935 (1), the pest was considered to be associated in this country merely with the former of the two hosts. Whilst its destructiveness to the Douglas fir is not to be minimized, it is no exaggeration to say that this notorious forest pest has assumed additional importance in Britain by the discovery of its galls. For it is recognized from Chrystal's account of its life-history and habits in America (2, 3) that it is a factor of greater potential damage to the Sitka spruce than to the Douglas fir.

Although the actual discovery of the galls at Glen Tress, Peeblesshire, by Mr. D. C. Ferguson, Lecturer in Forestry, Edinburgh University and myself, only dates from February 1935, it is probable, judging from the relation of dead galls of previous years still adherent to the host tree, that they became established three or four years ago. In view of the Scottish discovery it is interesting to note that a brief account of *Adelges cooleyi* was published by de Fluiter (4) in July 1934, but was not brought to my attention until after my paper (1) had appeared in October 1936. In his paper, de Fluiter tentatively records the existence of the gall of *A. cooleyi* on the Sitka spruce in Holland. His claim is based on the finding of but a single specimen said to resemble that of *A. cooleyi* illustrated by previous authors. Unfortunately, the record lacks that certain confirmation, which only the discovery of the antecedent foundress or stem-mother and the rearing of the subsequent gallicolae or gall-dwellers can supply. In this regard it may be mentioned that in 1928 my colleague, Mr. Ferguson, who had been on the look-out for the galls of *A. cooleyi* for several years, collected on Sitka spruce in the Forest of Dean a few specimens, which seemed to resemble the galls of the species in question. One of the specimens was submitted to Dr. R. N. Chrystal, Imperial Forestry Institute, Oxford, who commented on its resemblance to the gall of *A. cooleyi* both in regard to its shape and its involvement of the entire shoot. In his letter of acknowledgement to Mr. Ferguson, dated 14 December 1928, Dr. Chrystal, however, expressed himself as chary of giving a definite opinion on the identity of the gall in the absence of the stem-mother, of which a mere trace was discernible 'at some distance below the gall'. Nevertheless, this latter fact is not without significance, since the stem-mother of *A. cooleyi* frequently anchors itself on the twig at a distance of 2 to 3 inches from the apical bud, that may subsequently

be galled. Chrystal's caution is all the more interesting in the light of de Fluiter's conditional claim, apparently made in the absence or disregard of the stem-mother, that 'if his gall is identical with that of *A. cooleyi*', this would be the first record of its occurrence in Europe. By comparison, the discovery of the galls in Scotland (1) was published only after verification of their identity had been obtained by the finding of the stem-mothers and the gallicolae, both of which were reared. It is thus evident that the Scottish record is the first authenticated one of the occurrence in Europe not only of the galls, but also of the stem-mother (fundatrix vera) and the gallicolae, which had not hitherto been observed.

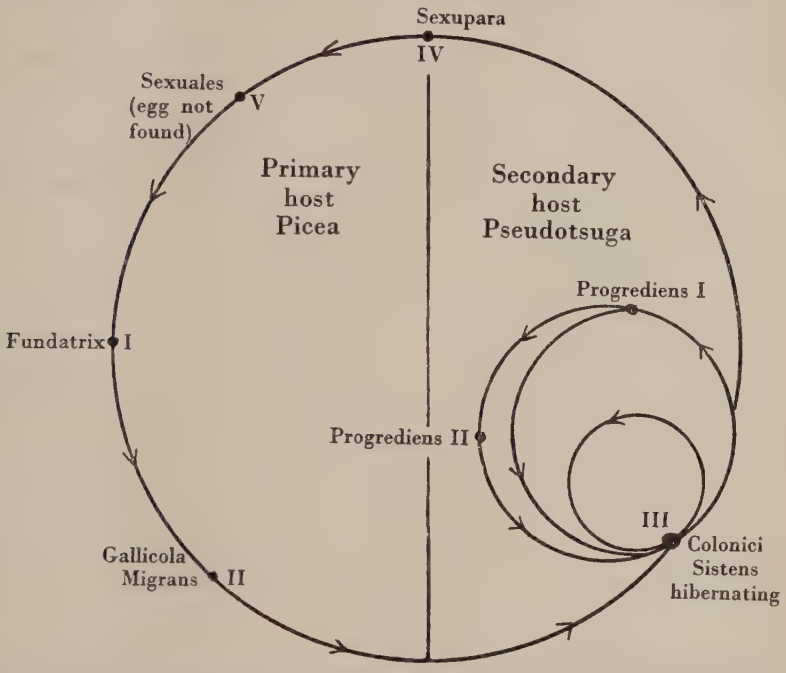
## THE LIFE-CYCLE IN THE LIGHT OF RECENT INVESTIGATION.

For the completion of its biennial life-cycle *Adelges cooleyi* requires two kinds of host, a primary, on which the fundatrix vera or foundress, the sexual generation and the gallicolae or gall-dwellers are reared, and a secondary, on which are produced the colonici and the sexuparae. Of primary hosts there had previously been recorded *Picea sitchensis*, *P. pungens*, and *P. engelmanni*. To these there must now be added *P. alba*, which was found to support the galls at Melrose, Roxburghshire (1). The secondary host is the Douglas fir, *Pseudotsuga douglasii*, of which the green or 'coast' variety is highly susceptible to attack, whilst the blue variety, *P. douglasii* var. *glauca*, is practically immune. Incidentally, the mere occurrence of the sexuparae of *A. cooleyi* on a species of spruce, on which the galls have not also been recorded, is insufficient to warrant its recognition as a true secondary host. *Picea alba* conforms to the necessary conditions, in that it is a host not only for the sexuparae but also for the galls and concomitant generations of the insect. By this same token the Norway spruce, *Picea abies* (*excelsa*), is not a true host. In 1936, sexuparae were frequently found on Norway spruce adjacent to infested Douglas fir, but the galls were not found on this tree. Similarly, Laing's record (5) of the occurrence of the sexuparae on *Picea nigra*, the black spruce, in Aberdeenshire, is interesting, but does not serve to establish this species as a true host. It is not inconceivable, however, that the adaptation of *A. cooleyi* to the white spruce, *P. alba*, may be repeated with the Norway spruce and the black spruce.

On the spruce host it is presumed that, sometime during July, the female of the sexual generation deposits a single fertilized egg, which, however, has not been found. That it does exist is inferred from the subsequent occurrence of the fundatrix vera (Plate XVII, fig. 1), the first-stage nymphs of which were overlooked in 1935 and first discerned at the end of March 1936 on the twigs of the previous year, where they had begun to secrete the characteristic waxen wool. Oviposition by the parthenogenetic mature instar of this generation begins in the field about the end of April, but may be considerably delayed by cold inclement weather. After a period of wintry conditions in the spring of 1936, which lasted from 11 to 23 April, the eggs, of which 300 to 500 per female are deposited, were not found out of doors until 1 May.

Hatching of the eggs follows in 7 to 10 days, and closely coincides with the

bursting of the buds, into which the first-instar gallicolae migrate, settling to feed at the base of the needles and on the central axis. The ultimate result of their feeding activities is a marked deviation of the normal process of bud development. A gall (Plate XVII, fig. 2) is formed in which the axial growth is retarded, and the bases of the needles swell and remain contiguous. In the chambers enclosed by the swollen needle-bases, the gallicolae complete their




Text-fig. 1. Graphical representation of the life-cycle of *Adelges cooleyi* Gillette, in Scotland, as described in the text. *After* Cameron, *Ann. App. Biol.* xxiii, p. 598.

development to the fourth instar, when the gall dehisces (Plate XVII, fig. 3) at the end of August and beginning of September to permit their escape. After a final moult which occurs outside the gall, the winged parthenogenetic gallicolae appear. Development and differentiation of the gall is accompanied by a sequence of striking colour changes. The initial green becomes overspread by a delicate pink stippling, which gradually deepens to purple. The stipples simultaneously increase in size until they coalesce, when the gall is now a uniformly deep purple. This contrasts with the dark green of the projecting needles. The purple coloration persists for about three weeks, when it gradually fades and is replaced by a bluish-green. The final change to the brown coloration of the dead gall ensues upon its dehiscence, dessication, and induration.

The length of the galls of *A. cooleyi* varies from 1½ to 3 inches according to the vigour of the attacked bud and the species of host spruce. On *Picea alba* they average not more than one-half to two-thirds the size of the average gall

on *P. sitchensis*. Usually the whole length of the shoot, at least on one side, is involved by the galling process, so that there is no subsequent growth beyond the gall. In this respect it differs from the gall of *Adelges abietis* (Plate XVIII, fig. 7), which is short and like a pine-cone. On the other hand, it resembles the gall of *Cnaphalodes strobilobius* (Plate XVIII, fig. 8) in terminating the growth of the shoot. The latter, however, is small, pale in colour, and the distal ungalled parts of the needles are shorter than those of the other two species. All three kinds of gall may occur simultaneously on the same host tree.

The winged gallicolae (Plate XVIII, fig. 5) migrate to the Douglas fir, where they reproduce parthenogenetically, laying 100 to 150 eggs, which hatch in 7 days to give rise to first-stage nymphs or sistentes. These, the beginning of the colonici generation, colonize the secondary host and hibernate on the needles. In March of the following year the sistentes (winter-brood I) complete their development (Plate XVII, fig. 4), and the mature stem-mother (fundatrix spuria) deposits parthenogenetically 40 to 60 eggs, from which there hatch three kinds of progeny as determined by their future history. Some immediately assume the hibernating condition, whilst others, after moulting three times, become wingless stem-mothers like their parents and constitute summer brood I (progrediens I). The remainder moults four times, and the winged fifth instar or sexupara (Plate XVIII, fig. 6) returns to the primary host. The stem-mothers of summer brood I and the sexuparae appear in June. The former deposit about 40 to 60 eggs, the majority of which hatch in 22 to 27 days to produce hibernating first-instar nymphs like those hatched from the eggs of the gallicolae. A certain small proportion, however, continues to develop into stem-mothers of the second summer brood (progrediens II), arriving at maturity in August. This second summer brood was first noted in 1935 and verified in 1936, when its numbers were smaller than in the previous year. Its progeny is entirely sistens.

From the foregoing brief account it will be readily appreciated that the hibernating first-stage nymphs of the colonist generation are a heterogeneous mixture composed of four categories as follows:

(1) Progeny of the gallicolae.
(2) Part of the progeny of winter brood I of the previous year.
(3) Part of the progeny of summer brood I.
(4) Progeny of summer brood II.

The separation of the various components of the colonici can be more readily comprehended by reference to Text-fig. 1, which is a graphical representation of the life-cycle of *A. cooleyi* in Scotland, constructed from data acquired in 1935 and 1936. It will be seen from the diagram that to the point on the lower right side of the large circle, there radiate four arcs, each corresponding to a distinct category. At the same time, the dimorphic nature of the progeny of the stem-mothers of winter brood I is expressed by the two arcs arising from a common stem and proceeding, the one to summer brood I, the other to sexupara.

So far as the Douglas fir is concerned, the first-stage nymphs of summer

brood I must be considered the distributive phase. Not only do they spread from the older needles, where they have hatched, to the young needles of the current year's shoots, but they creep down the branches and trunk of the infested tree to the ground; or they may arrive there by voluntary dislodgment from the needles. Whatever the method, the vegetation underlying the trees in young plantations becomes overspread with a coating of the minute brown insects. Many perish from starvation and the effect of low ground-temperatures, but the survivors contrive to ascend the trunks of available Douglas firs. The migration of descending and ascending individuals was readily verified by direct observation of their movements over the surface of white paper bands, 8 inches wide, which were securely attached to the trunks of infested Douglas firs. The nymphs were also found on the needles and branches of Sitka and Norway spruces overlapped by the branches of infested Douglas fir. They likewise were found to occur on spruce trees, Sitka and Norway, which were not contiguous to the infested secondary host. In this instance it was presumed that they had been casually borne by the wind, which is probably the chief factor in determining the uniform spread of the species throughout a plantation of Douglas fir. The first-stage nymphs, which had alighted on the spruce needles, failed to develop further and finally perished. Thus the great fecundity of the colonial stem-mother is considerably offset by the high percentage mortality, which attends the unavoidable mistakes made by its progeny. Incidentally, the predatory activities of the larvae and adults of the ladybird beetle, *Adalia obliterata* L., the most important of the natural enemies of *A. cooleyi* in Scotland, exert but an unappreciable check on the multiplication of the colonici.

Whilst the partial life-cycle, involving the colonici only, may be repeated indefinitely on the Douglas fir, it is completed on the primary host—all other conditions being favourable—by the medium of the winged migrant sexuparae and subsequent generations. In the absence of a suitable secondary host, the migration of the sexuparae is attended by considerable wastage. They settle on the undersurface of the needles of Sitka spruce and by reason of their vast numbers and copious secretion of waxen wool (Plate XVIII, fig. 6), they may temporarily change the aspect of the tree from green to white. The migration from Douglas fir to Sitka spruce occurs in June and July, and soon after settling each parthenogenetic female lays 10 to 25 eggs, that hatch in 7 to 12 days to introduce the sexual generation.

This latter generation was investigated in 1935, when only a comparatively few mature individuals were recovered, the majority being males. In 1936, close attention was paid to this generation with the result that its five stages, including numerous specimens of both sexes, were obtained and studied. The wingless males and females are minute; although it passes through 4 moults, the mature individual is very little larger than the first instar, which emerges from the egg. So far, oviposition has not been observed, and the solitary egg has not been found. As in the case of the first instars of summer brood I and of the sexuparae, which fail to find a suitable primary host, likewise in the

sexual forms—for some reason or reasons not presently accountable—the percentage mortality is very high. This in part explains the relatively small numbers of the subsequent foundress generation.

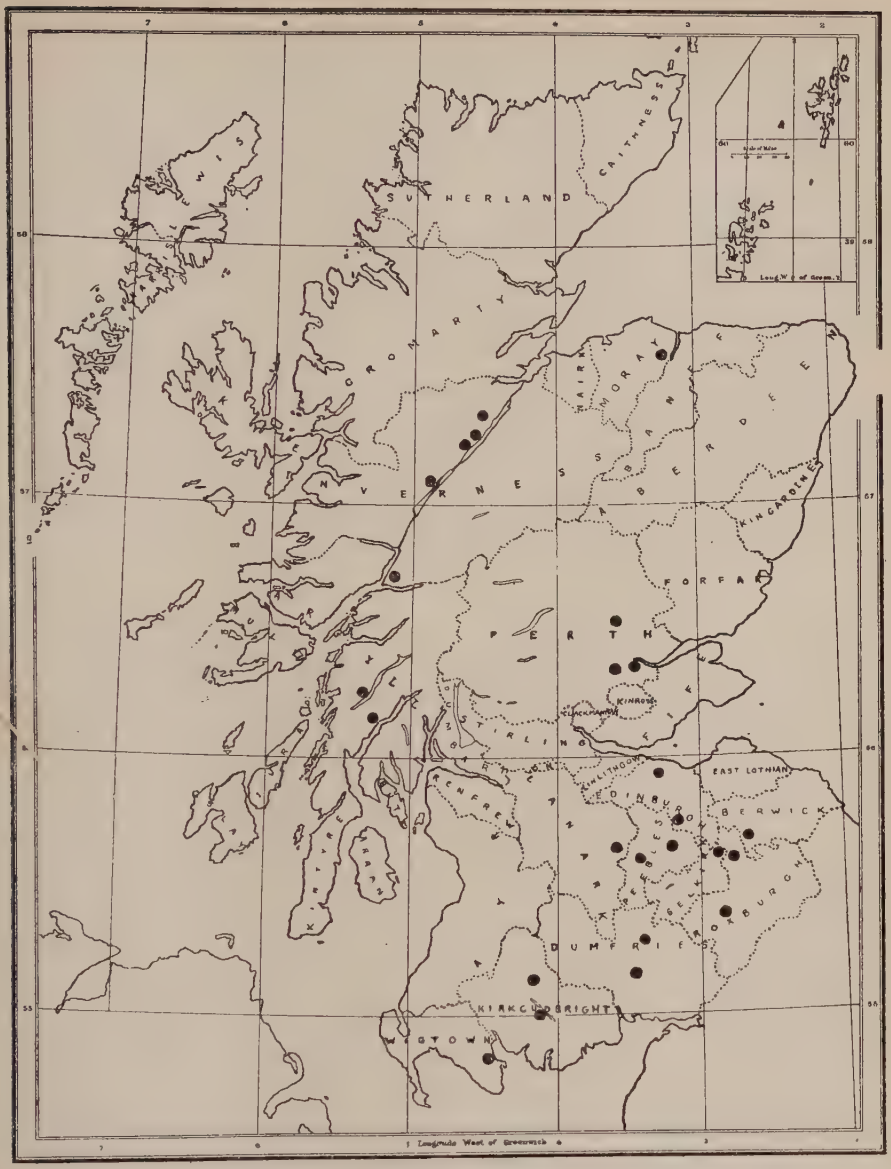
DISTRIBUTION OF THE GALLS IN SCOTLAND.

In 1935 the galls of *A. cooleyi* were discovered in various plantations of the counties of Peebles, Roxburgh, Selkirk, Edinburgh, and Perth. These were recorded in my paper recently published (1). As a result of a more extensive survey in 1936, the following counties can now be added to the foregoing list, namely, Ross and Cromarty, Inverness, Argyll, Lanark, Kirkcudbright, Dumfries, and Berwick, together with Moray and Wigtown, records from which and from Ross were kindly furnished by Mr. J. M. Murray, Assistant Forestry Commissioner for Scotland. These last three counties I was unable to visit, and Mr. Murray also supplied a record of the occurrence of the galls in a plantation in Kirkcudbrightshire, other than those which were examined by me. With the exception of the one record of *Picea alba* from Roxburghshire, on which dead galls were discovered in 1935 and living ones in 1936, the trees infested by the galls were invariably *P. sitchensis*.

A review of the data acquired in the course of the survey reveals that the spruce generations of *A. cooleyi*, judged from the number of galls per infested tree, have become more firmly established in the counties of Wigtown, Kirkcudbright, and Peebles than elsewhere. There is, however, considerable variation in the numbers of galls in different plantations in the same county, depending upon the relative proximity of infested Douglas firs to Sitka spruce and the kind of weather conditions, especially those prevailing in April and May. Generally speaking, the galls are more plentiful on trees at, or near, sea-level than at higher elevations inland, where the fundatrix vera, its eggs, and the first-stage gallicolae are more liable to the lethal action of spring frosts. It is thus not improbable that the firmer establishment of the spruce generations of *A. cooleyi* in the southern counties of Scotland, as contrasted with the northern (Text-fig. 2), is in some degree correlated with their milder and more favourable weather conditions. North of the county of Edinburgh, the survey showed that galls were relatively few in Morayshire, Inverness-shire, Ross-shire, Argyllshire, and Perthshire, with two exceptions, the one a plantation on the shores of Loch Linnhe and the other on the shore of Loch Fyne. At the same time, it must be remembered that the survey was not exhaustive and embraced but a fraction of the Sitka spruce—Douglas fir plantations of the country. It did not extend farther north than the shores of Loch Ness. So far, the galls have not been recorded from parts of the British Islands other than Scotland. The suspected galls collected by Mr. Ferguson in the Forest of Dean in 1928, upon which comment was made on page 133, cannot, for lack of evidence, be accepted as a record.

A FACTOR RESTRICTING THE GALL GENERATION.

From actual observation it was ascertained that unseasonable frosts in April, after the foundress or fundatrix vera has emerged from hibernation and com-




TEXT-FIG. 2. Map showing the distribution of the galls of *A. cooleyi* in Scotland. The black dots indicate the position of the localities where the galls were found. Note the greater concentration of these localities in the southern counties.

menced to feed and develop, destroy large numbers of this generation. In 1936, in a forest plantation in Peebles-shire, temperatures of 23, 20, 25, and 21° F. were recorded on the nights of 20 to 23 April respectively. At this time individuals of the foundress generation were in the third or fourth stages.

Specimens of the insects were collected at random from various Sitka-spruce trees distributed through the forest. Examination showed that about 65 per cent. of the foundresses had been destroyed by the frost. The buds, as yet unopened, were not affected by the frost. During the previous year, in the same plantation, temperatures of 24, 23, and 23° F. were recorded on 15 to 17 May respectively at a time when the eggs laid by the foundresses had hatched to produce the first-stage gallicolae. The latter were now inside the burst buds, and the frost not only encompassed their destruction but created havoc with the buds. As a result the number of galls that arrived at maturity in this particular plantation in 1935 was much reduced.

From these two sets of observations it will readily be appreciated that freezing temperatures in April, provided they are not too low to affect the unburst buds adversely, serve to favour the primary host at the expense of its injurious pest. The production of galls is diminished in proportion to the degree of mortality induced in the foundress generation by the lethal action of the frost. On the other hand, the beneficial effects of low temperature in May, which destroy the young gallicolae, are counter-balanced by the increased susceptibility to frost damage of the burst buds.

SUMMARY.

*Adelges cooleyi*, the so-called 'woolly-aphis' of Douglas fir, its secondary host, is native to North America and was first recorded in Britain in 1913. Its primary host is one or other species of spruce, including *Picea sitchensis*, *P. pungens*, and *P. engelmanni*, on which the galls are found in America. Galls recognized as those of *A. cooleyi* were first discovered on Sitka spruce in Britain near Peebles in 1935. Later in the same year they were recovered from a new host, the white spruce, *P. alba*, in Roxburghshire. They have not been found to occur on Norway spruce. The finding of the galls here described is the first authenticated record of their occurrence in Europe. The discovery of the fundatrix vera or stem-mother and the gallicolae or gall-dwellers likewise assumes priority of record so far as Europe is concerned.

As a result of studies conducted in the laboratory at Edinburgh University and in the open in Peebles-shire and elsewhere in Scotland, the life-history of *A. cooleyi*, hitherto considered to be incomplete in Britain, has now been shown to be complete—a natural corollary of the discovery of the two hitherto missing generations. On the Douglas fir, the existence of two summer broods of colonici or colonists has been proved, of which the second is of relatively small proportions. In 1936 it was almost negligible. The various stages of all five generations of the life-cycle have been found in Scotland, with the exception of the egg laid by the sexual female, which also awaits discovery in America.

In 1935 the galls of *A. cooleyi* were recorded from five Scottish counties; in 1936 the number was increased to fourteen,[1] embracing twenty-eight separate localities. It is not presumed that their distribution is limited to these localities only.

[1] See note on p. 142.

The degree of infestation of the spruce host depends not merely on the relative proximity of infested Douglas firs but also on certain other factors, which are beyond human control. To some of these, yet unknown, is attributed an annually recurrent high mortality of the sexual generation; to others, contingent on vagaries of the weather, is due the occasional destruction of large numbers of the foundresses and gall-dwellers. Temperatures of 9 to 12° F. below freezing-point are lethal to the foundresses in April and to the later developing gall-dwellers in May. Whereas April frosts are not attended by any appreciable damage to the unburst buds of the Sitka spruce, May frosts may result in irreparable damage to the more susceptible burst buds.

The present economic status of the gallicolae on Sitka spruce has not been definitely assessed. They are more firmly established in the southern counties of Scotland and are more abundant in Wigtownshire, Kirkcudbrightshire, and Peebles-shire than elsewhere. Even so, the infestations could not be described as other than light, and no tree was encountered during the course of the investigation that could be said to be seriously damaged by the galls. Nevertheless, it will be necessary to keep a close watch for developments on the plantations where galls have been or may be found.

ACKNOWLEDGEMENTS.

For the defrayal of expenses incurred in prosecuting the investigation of the biological aspects of the problem, two grants, the one in 1935 and the other in 1936, were obtained from the Earl of Moray Endowment of Edinburgh University. To the Forestry Commission of Great Britain I am indebted for a grant which enabled me to conduct the survey of gall distribution in Scotland in 1936. Mr. J. M. Murray, Assistant Forestry Commissioner for Scotland, was particularly helpful with advice concerning plantations where galls of *A. cooleyi* might be found. Mr. Murray also kindly supplied records of the occurrence of galls in six localities.

Text-figure 1 and the figures of Plates XVII and XVIII have been borrowed from my paper on *Adelges cooleyi*, which was published in the *Annals of Applied Biology*, vol. xxiii, No. 3, 1936. For permission to reproduce these I am indebted to the editors of that journal.

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## EXPLANATION OF PLATES

PLATE XVII.

Fig. 1. Foundress or stem-mother (fundatrix vera) of *Adelges cooleyi*, covered with wool, at the base of an apical burst bud of Sitka spruce, *Picea sitchensis*. The stem-mother had laid its eggs, which had hatched at the time the photograph was made. The resulting young gallicolae had entered the apical bud, which is seen to be retarded in its growth as compared to the right lateral bud. The apical bud is an incipient gall. The left lateral bud had been killed by frost. $\times\frac{5}{6}$. Original.

Fig. 2. Unopened gall of *Adelges cooleyi* on Sitka spruce. $\times\frac{5}{6}$. Original.

Fig. 3. Open dead gall of *Adelges cooleyi* on Sitka spruce. $\times\frac{5}{6}$. Original.

Fig. 4. *Adelges cooleyi*, colonici, on Douglas fir in summer. The needles are heavily infested with the stem-mothers obscured by their waxen secretions. Hibernating first-stage nymphs are also discernible under a magnifying lens. $\times\frac{5}{6}$. Original.

PLATE XVIII.

Fig. 5. Winged gallicolae, *Adelges cooleyi*, ovipositing on a needle of Douglas fir. $\times 20$. Original. (Phot. R. Carrick.)

Fig. 6. Winged sexuparae, *Adelges cooleyi*, on needles of Sitka spruce. The photograph illustrates their abundance. $\times\frac{5}{6}$. Original.

Fig. 7. Unopened gall, *Adelges abietis*, on Sitka spruce. Compare with Fig. 2. $\times\frac{5}{6}$. Original.

Fig. 8. Unopened gall, *Cnaphalodes strobilobius*, on Sitka spruce. Compare with Fig. 2. $\times\frac{5}{6}$. Original.

*Note*: Records of the occurrence of galls of *A. cooleyi* on Sitka spruce at North and South Strome, and Achnashellach, Ross-shire, were supplied to me by Mr. J. M. Murray after the manuscript had been sent to the press and too late to be included in the map of Text-fig. 2. They have, however, been included in the text. Thus, although only twenty-five localities are indicated on the map, twenty-eight are mentioned on page 140, including the three from Ross-shire. Likewise, the distribution of the galls by counties involves fourteen, one more than shown on the map.

PLATE XVII

PLATE XVIII

# THE INFLUENCE OF CELL-WALL COMPOSITION ON THE PHYSICAL PROPERTIES OF BEECH WOOD (*Fagus sylvatica* L.)

BY S. H. CLARKE

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THE density of wood is usually regarded as the best single indicator of its technical properties, but it is well known that in most species wide variations in certain mechanical properties occur among specimens having the same density. Attempts to account for the unexplained variations have indicated that strength is apparently dependent to a large extent on physico-chemical characteristics which may or may not be detected by microscopic examinations. In ash, for example, microchemical staining reactions may reveal differences in the cell walls of specimens apparently identical in density and structure but differing widely in strength (3).

An abnormality occurring in the fibres of many important hardwood timbers in a greater or less degree is the development of a special type of thickening layer that has been variously described as 'cellulosic', 'gelatinous', 'mucilaginous', 'cartilaginous', or 'tertiary' wall formation. Although the addition of this layer must augment the specific gravity of the wood, investigations in this laboratory have shown that it does not increase the mechanical strength in the same proportion (1). These observations have recently been extended by work on the structure-strength relations of beech (*Fagus sylvatica* L.), a diffuse-porous hardwood, in contrast to the ring-porous ash and elm which were the basis of the studies referred to above. It may be observed that as a rule the growth rings of diffuse-porous hardwoods show no marked differentiation of springwood and summerwood, and no general relation has been observed between their growth rate and either density or strength. Consequently, in seeking to explain the variations unaccounted for by specific gravity, attention turns naturally to variations in the physico-chemical nature of the cell walls, and to variations in arrangement of the wood substance such as might influence the thickness of the fibre walls (fibre-wall thickness having been found to be of importance in ash (2)). It has been possible to show that the nature of the fibre walls influences several properties of the wood, and that it is probably more important than specific gravity in its effect on mechanical strength.

## MATERIAL AND METHODS.

It is the custom of the Timber Mechanics Section of the Forest Products Research Laboratory to retain a small portion of each specimen tested in compression parallel to the grain, and at the beginning of the present investiga-

tion approximately 1,000 such specimens of beech were available for study. These represented:

5 trees from Knightswood, Hants. (Consignment No. T.M. 10).
5 trees from Chenies, Bucks. (Cons. No. T.M. 23).
10 trees from Brocklesby, Lincs. (Cons. Nos. T.M. 24 and T.M. 35).
5 trees from Mapledurham, Oxon. (Cons. No. T.M. 40).
5 trees from Temple Guiting, Glos. (Cons. No. T.M. 46).
6 trees from Arundel Park, Sussex (Cons. No. T.M. 57).

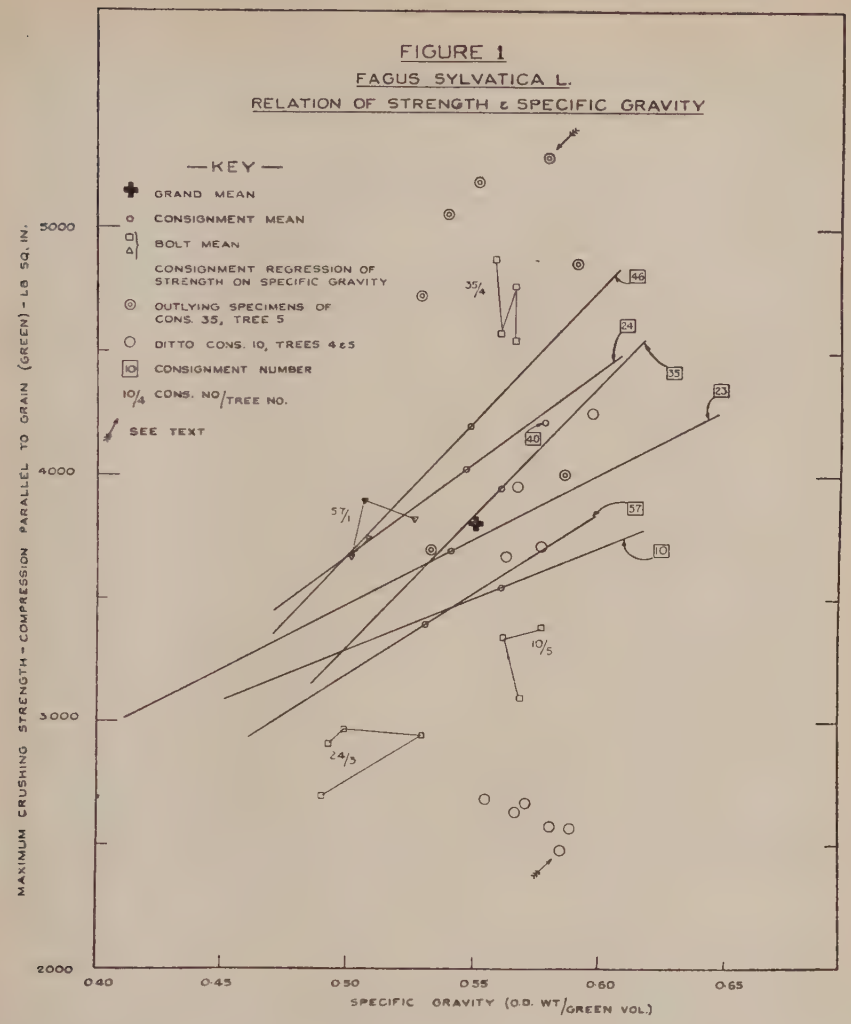
The maximum crushing strength in compression parallel to the grain and the specific gravity (oven dry weight/green volume) of each specimen had been determined by the Timber Mechanics Section, and regressions of strength on specific gravity were drawn for each consignment (Text-fig. 1). The mean specific gravity and mean strength of specimens from each bolt, or log, were plotted, and the points fell in groups around the tree means, and were scattered on either side of the consignment regressions. From an inspection of these points three pairs of trees were selected, so that while the means of each pair were roughly similar in specific gravity they differed considerably in strength. To avoid confusion the values for only two pairs of these trees, selected as typical, are shown in Text-fig. 1. Outlying specimens[1] were then selected from each of these trees (to avoid confusion the values for specimens from only three representative trees are shown in Text-fig. 1), and all the outlying specimens having specific gravities of 0·52 and 0·58 were chosen, so as to have representatives from a greater number of trees, and from all the localities.

Much of the work necessary in studying the interrelation and the relative importance of factors influencing strength was greatly simplified by using the Paramount Sorting System. The application of this system in the study of related variables is described elsewhere (4).

## COMPARISON OF OUTLYING SPECIMENS.

From a superficial examination the selected outlying strong and weak specimens were usually as similar in structure and general appearance as they were in density. Many of the abnormally weak specimens, however, presented a silky, lustrous appearance on the sawn end-grain. Transverse sections (thickness 20 $\mu$) of all specimens were mounted in glycerine jelly to which gentian violet had been added (about 20 drops of saturated aqueous solution of gentian violet per 100 c.c. jelly). Microscopic examination of these sections showed that without exception the weak outlying specimens were characterized by the presence of abnormal gelatinous-looking fibre walls which were coloured only palely or not at all by the gentian violet (Plate XIX, Fig. 3), in contrast to the deeply staining middle lamellae and primary walls. The abnormal layers were

[1] When two related features such as a strength property and specific gravity are plotted the points for individual specimens are dispersed over an elliptical area, the major axis of which represents the general trend of the relation. Specimens the points for which lie towards the periphery of the ellipse are said to be 'outlying specimens'. These show the extreme influence of other factors determining strength.




*Points to be noted in Text-fig.* 1.

Each consignment has a characteristic regression: for instance, at specific gravity 0·55 material of Cons. No. 46 is on the average about 700 lb. per sq. in. stronger than that of Cons. No. 57.

Bolt means of individual trees fall in groups (around the tree means) which are scattered on either side of the consignment regressions. (To avoid confusion, only 5 trees are illustrated.)

The values of individual specimens are scattered about the bolt means, the outlying specimens showing considerable deviations from these. The individual specimens of one tree may be quite distinct from those of another; the strongest of Cons. 10, tree 4, are practically equal in strength with the weakest of Cons. 35, tree 4.

The members of one pair of specimens (indicated by arrows) of similar specific gravity differ by 2,800 lb. per sq. in. in strength.

similar in appearance to those observed in elm (1) and many other hardwoods, and in most cases were abundant and strongly developed, particularly in the earlier parts of the annual ring. Such fibre walls were, on the other hand, absent from, or but feebly developed in, the strong outlying specimens (Plate XIX, Fig. 2).

Other sections from the same material were treated with chlor-zinc-iodine, and others again with a solution of phloroglucin in hydrochloric acid; these reagents were also effective in differentiating between the normal secondary walls and those which showed abnormal thickening. In the case of the phloroglucin the middle lamella stained a deep crimson and the secondary wall pinkish to reddish, the abnormal thickening layer remaining unstained. The staining reactions of the fibre walls of ash (3) are thus recalled, and it would appear possible that the feebly staining walls of certain ash samples represent a condition similar to that found in elm and beech.

Several combinations of stains were used to differentiate the various degrees of abnormal development, and gossypimine counterstained by light green was found to be the most satisfactory combination. In addition to giving a good colour contrast, the light green was effective in detecting comparatively small degrees of the condition described as abnormal. With this combination the vessel, ray, and vertical parenchyma walls always stained a deep red, but a definite gradation of staining reactions was shown by the fibres. In outlying strong samples all parts of the fibre walls also stained red, though not infrequently the middle lamella took a deeper colour than did the secondary wall. At the other extreme, in zones of certain outlying weak specimens, the middle lamella of the fibres stained a fairly deep green and the abnormal thickening layer a very pale green. Many intermediate stages were found, and not infrequently these occurred within the limits of a single section, for even in the weakest specimens a narrow band of summerwood took the red stain, the width of this band varying with the specimen and also in different rings on one and the same specimen. Sometimes the secondary walls had a purplish tinge, suggesting that they were stained partly by the light green, and sometimes the middle lamellae were bright red and the secondary walls bright green. The proportion in which any particular type of staining occurred varied from ring to ring in single specimens; in some rings, for instance, gelatinous-looking walls were abundant, whereas in neighbouring rings they were present only in a few isolated fibres.

A quantitative relation between the composition of the fibre walls and strength was indicated, on the one hand, by the high proportion of fibre-wall substance taking the green stain in extremely weak material and, on the other, by the absence or paucity of green-staining material in the strong specimens. Unfortunately no accurate numerical expression could be found for the variations in cell-wall composition, but on dividing the available specimens into five groups on a rough visual estimate of the amount of wall substance staining green with the gossypimine-light green combination, it was at once evident that the specimens in the groups with high proportions of green-staining

tissue were particularly weak irrespective of their specific gravity. Moreover, it was demonstrated (4) that strength and specific gravity were much more closely related in the groups without abnormally thickened fibre walls than in the groups with them, or than in unsorted material (i.e. in all the groups taken together).

It is of interest at this point to refer to the peculiar beech shoe-last block illustrated in Plate XIX, Fig. 1. The block was roughly turned in the green condition, when it was observed that whereas one half (*a*) presented a moderately smooth surface, the other (*b*) was distinctly 'woolly'. During the seasoning process the block split, as shown in the photograph, and the longitudinal shrinkage of the wood on the one half (*b*) of the split was distinctly more than that shown by the other side (*a*). Microscopic examination revealed abundant gelatinous-looking thickenings in the fibres of portion (*b*), but none in portion (*a*). There are other instances of the technical properties of timber being affected by similar abnormalities in the structure of the fibre walls. The quality of oak and elm is materially affected by the abnormal development of gelatinous-looking fibres, and Mr. B. J. Rendle, of this Laboratory, has found that a woolly machine finish on certain specimens of an African mahogany (*Khaya anthotheca*) is associated with the same phenomenon. It would appear, therefore, that the nature of the cell wall is capable of influencing not only the strength, but also the working properties and the shrinkage of wood to an important degree.

## VARIATIONS IN THICKNESS OF THE FIBRE WALL.

The pair of samples illustrated in Plate XIX, Figs. 4 and 5, show that fibre wall thickness may vary at any given specific gravity, the variations being accompanied by balancing variations in pore volume. In the material examined it was not found possible to demonstrate a significant relation between such variations and mechanical strength.

## DISCUSSION.

Reference to Text-fig. 1 will show that within the range encountered, variations in specific gravity were responsible for strength variations of about 1,000–1,500 lb. per square inch, and differences of 2,000 lb. per square inch were not uncommon in specimens matched in respect of specific gravity. In an extreme case a pair of specimens identical in specific gravity differed by 2,800 lb. per square inch in strength (see arrows in Text-fig. 1). It may safely be concluded that the influence of cell-wall composition on strength is at least as great as that of specific gravity, and appears in some cases to be even greater. Cell-wall composition must be regarded as of primary importance, however, not only on account of the magnitude of its influence on the properties of wood but also because it acts as a limiting factor. Evidence of this is found in the observation that the relation between strength and specific gravity in a collection of specimens becomes closer when all those with abnormally thickened fibre walls are removed; and also in the pronounced change in the properties accompanying the formation of these walls in the beech shoe-last.

A consideration of the staining reactions described suggests that the variations in cell-wall composition are linked with the degree of lignification, but the uncertainty at present surrounding our knowledge of the significance of these reactions forbids definite conclusions to be drawn. Moreover, little is known of the influence of growth conditions on the composition of the cell wall, and at present one can only speculate as to the cause of abrupt changes in the composition of the fibre walls as exemplified in an extreme degree in the specimen illustrated in Plate XIX, Fig. 1. It is hoped to investigate the matter further as suitable material becomes available.

SUMMARY.

Under certain conditions the fibre-walls of beech and many other hardwood timbers develop peculiar thickening layers that have been called 'gelatinous layers' or 'tertiary walls'. The presence and the degree of development of these thickenings in selected samples of beech was studied by the use of various microchemical stains. It is shown that samples with large proportions of these abnormal thickenings usually have low values in strength in compression parallel to the grain, and that cell-wall composition is probably more important than specific gravity in its influence on strength.

It is further shown by an example that cell-wall composition is capable of influencing the shrinkage and working properties of beech.

ACKNOWLEDGEMENTS.

The author is indebted to Mr. W. A. Robertson, Director of Forest Products Research, for permission to publish this article, and to his colleagues in the Timber Mechanics Section for their invaluable co-operation.

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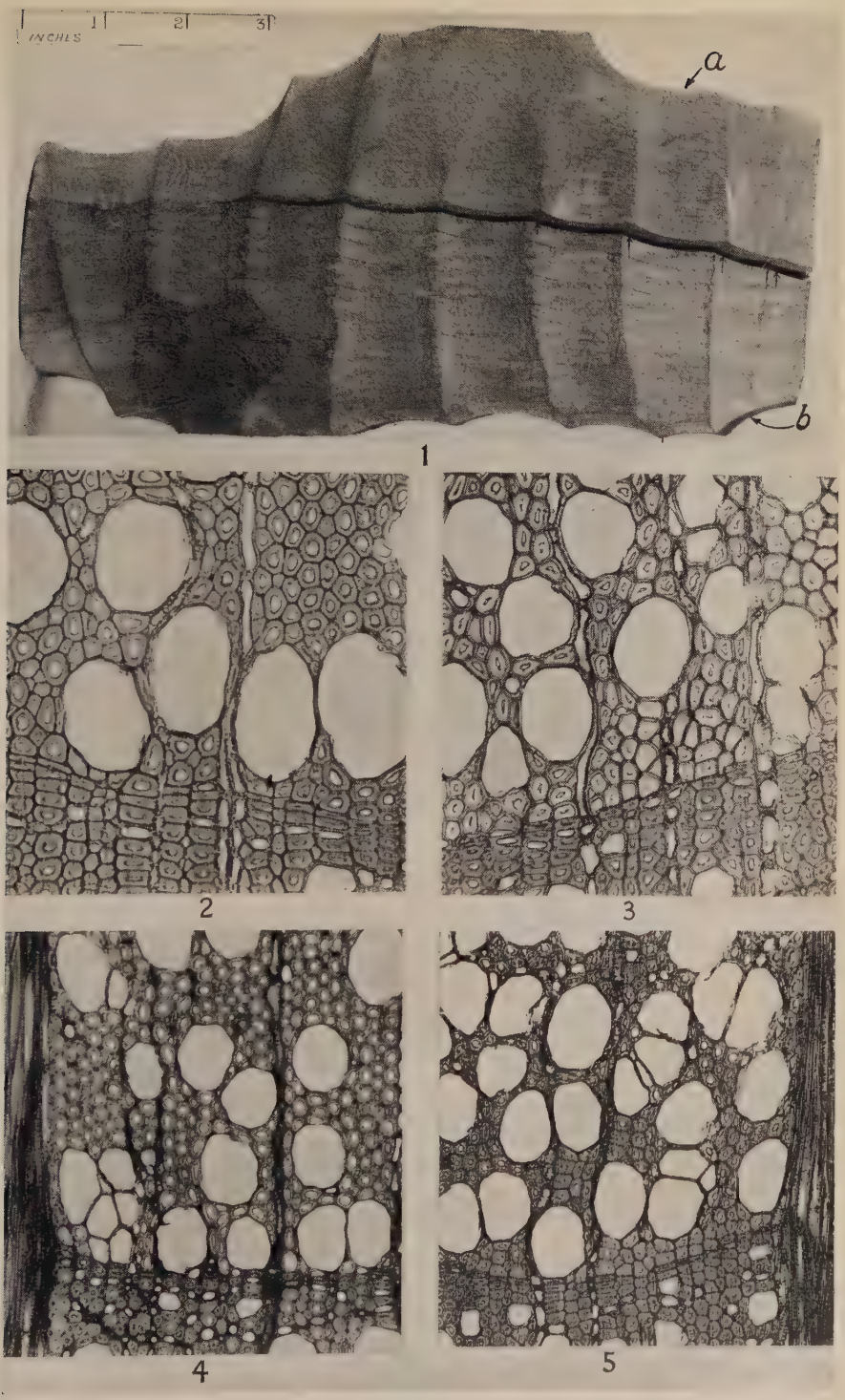
## EXPLANATION OF PLATE XIX

Fig. 1. Beech shoe-last block.

Fig. 2. Photomicrograph (× 200) of transverse section of beech, stained with gentian violet. Specific gravity (oven dry weight/green volume) 0·52; maximum crushing strength 4,640 lb. per sq. in.

Fig. 3. Photomicrograph (× 200) of transverse section of beech stained with gentian violet. Specific gravity (oven dry weight/green volume) 0·52; maximum crushing strength 2,290 lb. per sq. in. Note abnormal thickening of fibre walls.

Figs. 4 and 5. Photomicrographs (× 140) of transverse sections of beech stained with gentian violet. Specific gravity of both specimens approximately 0·69. Note differences in pore volume and in fibre wall thickness.




*Fagus sylvatica* L.
(for explanation see text)

PLATE XIX

# ANALYSIS OF MINERAL CONSTITUENTS IN CERTAIN FOREST SOILS IN NORTH-EAST SCOTLAND

BY J. M. SHEWAN

(The Macaulay Institute for Soil Research, Craigiebuckler, Aberdeen)

ALTHOUGH much analytical work has been carried out in connexion with profile examination of soils it is seldom that results are recorded for the surface layers, which are usually grouped together as the $A_0$ horizon. Hesselman (2) studied the humus layers of a number of forest profiles, but only gives values for the reaction, and for the calcium and nitrogen contents among mineral constituents.

To obtain some data of this nature for forest soils in North-East Scotland five profiles were selected—two under spruce, two under beech, and one under Scots pine. These are described in detail below. The $A_0$ layers were subdivided into the loose litter (LL) layers and the 'F' and 'H' horizons of Hesselman. Only the $A_0$ and $A_1$ horizons were analysed. The samples were air dried, ground, and ashed in a platinum vessel over a low flame, after which the mineral constituents were determined by the normal analytical procedure (1). In addition to the ash constituents values for Carbon (by Wet Combustion) (3), and Nitrogen (by Kjeldahl) were determined on two of the profiles and for pH (Quinhydrone electrode) on the moist samples from all profiles.

## PROFILE DESCRIPTIONS.

*Profile* 1.

*Locality:* Hazlehead, Countesswells, Aberdeenshire.
*Soil*: Podsol on morainic drift derived from Granitic and Gneissic material.
*Site:* On gently sloping ridge, 450 feet O.D.
*Vegetation:* Beech wood with an occasional spruce and Scots pine; *Vaccinium Myrtillus* and *Calluna vulgaris*.

| | | |
|---|---|---|
| $A_0$ (1) | 0–2 cm. | Layer of newly fallen beech leaves ($LL_1$ layer). |
| (2) | 5–7 cm. | Compact leaf litter; partially decomposed, light yellow to brown in colour with many rootlets ($LL_2$ layer). |
| (3) | 7–10 cm. | Dark brown well decomposed layer with many rootlets, still showing part of plant structure (F layer). |
| (4) | 10–15 cm. | Black peaty layer, with some mineral constituents and dead roots—fairly compact (H layer). |
| $A_1$ | 15–20 cm. | Black humus layer, compact, much mineral matter and roots. |

*Profile* 2.

*Locality:* Pitfour Mintlaw, Aberdeenshire.
*Soil:* Recent alluvial sand on Quartz Schist.

*Site:* Flat terrace, 300 feet O.D.

*Vegetation:* Spruce wood, no ground vegetation where samples were taken.

$A_0$ (1) 0–1 cm. Thin covering of undecomposed spruce needles of varying depth (LL layer).

(2) 1–6 cm. Darker layer of partially decomposed spruce needles—loose in texture, friable, with many rootlets and little mineral matter (F layer).

(3) 6–7 cm. Thin layer of well decomposed needles—not compacted and with fair amount of mineral matter (H layer).

$A_1$ layer 7·0–8·0 cm. Dark humus layer with much mineral material, compact, and many rootlets.

*Profile* 3.

*Locality:* Pitfour, Mintlaw, Aberdeenshire.

*Soil:* Podsol on sand from Quartz Schist.

*Site:* Gently sloping ridge, 350 ft. O.D.

*Vegetation:* Beech wood newly felled. No surface vegetation where samples were taken.

$A_0$ (1) 0–5 cm. Loose leaf litter, layer of undecomposed beech leaves (LL layer).

(2) 5–6 cm. A mat of compact partially decomposed leaves, some light yellow in colour, with numerous rootlets and very little mineral matter (F layer).

(3) 6–6·25 cm. Thin layer of black, well decomposed organic material showing little or no structural form (H layer).

$A_1$ 6·25–11·0 cm. Black humus layer, compact with much mineral matter and many roots.

*Profile* 4.

*Locality:* Countesswells, Aberdeenshire.

*Soil:* Podsol on Mixed Granite-Gneiss Morainic Drift.

*Site:* Flat or gently sloping ridge, 400 feet O.D.

*Vegetation:* Spruce wood, with an occasional Scots pine, little or no ground vegetation where samples were taken.

$A_0$ (1) 0–1 cm. Layer of newly fallen spruce needles. Variable in thickness (LL layer).

(2) 1–4 cm. Brown compact layer of partially decomposed spruce needles—with rootlets (F layer).

(3) 4–9 cm. Layer of black well-decomposed organic material, variable in thickness, many roots and fairly compact (H layer).

$A_1$ 9–19 cm. Brownish humus layer with much mineral matter and many large quartz particles; compact.

*Profile* 5.

*Locality:* Ballochbuie Forest, Braemar, Aberdeenshire.

*Soil:* Podsol on Granitic Glacial Sand.

| | PROFILE 1 Hazlehead Beech | | | | | PROFILE 2 Pitfour Beech | | | | PROFILE 3 Pitfour Spruce | | | | PROFILE 4 Countesswells Spruce | | | | PROFILE 5 Ballochbuie Scots Pine | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | $LL_1$ | $LL_2$ | $F$ | $H$ | $A_1$ | $LL$ | $F$ | $H$ | $A_1$ | $LL$ | $F$ | $H$ | $A_1$ | $LL$ | $F$ | $H$ | $A_1$ | $LL$ | $F$ | $H$ | $A_1$ |
| Ash | 5·46 | 7·02 | 8·27 | 55·52 | 82·66 | 5·08 | 8·12 | 14·42 | 68·49 | 12·50 | 11·32 | 47·58 | 83·08 | 6·64 | 8·71 | 17·68 | 42·70 | 2·91 | 2·49 | 2·63 | 16·21 |
| Sol. in HCl. | 2·21 | 2·07 | 1·88 | 3·38 | 5·70 | 2·57 | 3·01 | 3·59 | 6·74 | 3·47 | 3·60 | 6·77 | 10·90 | 3·40 | 2·74 | 3·01 | 3·98 | 2·00 | 1·45 | 1·35 | 4·07 |
| $Fe_2O_3$ | 0·100 | 0·192 | 0·204 | 1·065 | 2·084 | 0·141 | 0·315 | 0·745 | 2·499 | 0·265 | 0·378 | 1·929 | 3·150 | 0·150 | 0·141 | 0·582 | 0·559 | 0·070 | 0·093 | 0·123 | 2·56 |
| $Al_2O_3$ | 0·316 | 0·416 | 0·497 | 1·603 | 2·698 | 0·279 | 0·699 | 1·375 | 3·411 | 1·275 | 1·125 | 3·059 | 4·405 | 0·193 | 0·082 | 1·241 | 2·501 | 0·153 | 0·067 | 0·180 | 0·845 |
| $Al_2O_3$ $Fe_2O_3$ | 3·2 | 2·2 | 2·4 | 1·5 | 1·3 | 2·0 | 2·2 | 1·9 | 1·4 | 4·7 | 3·0 | 1·60 | 1·4 | 1·3 | 0·60 | 2·1 | 4·5 | 2·2 | 0·73 | 1·5 | 0·33 |
| MnO | 0·058 | 0·059 | 0·012 | 0·010 | Trace | 0·044 | 0·054 | 0·038 | 0·034 | 0·123 | 0·118 | 0·022 | 0·034 | 0·101 | 0·109 | 0·004 | Trace | 0·062 | 0·031 | 0·005 | Trace |
| CaO | 0·840 | 0·704 | 0·419 | 0·244 | 0·229 | 1·126 | 1·063 | 0·649 | 0·220 | 1·005 | 1·176 | 0·394 | 0·223 | 1·898 | 1·345 | 0·619 | 0·195 | 1·037 | 0·559 | 0·436 | 0·183 |
| MgO | 0·164 | 0·156 | 0·149 | 0·179 | 0·195 | 0·326 | 0·309 | 0·280 | 0·295 | 0·263 | 0·267 | 0·376 | 0·493 | 0·164 | 0·143 | 0·145 | 0·185 | 0·120 | 0·092 | 0·225 | 0·062 |
| $K_2O$ | 0·102 | 0·121 | 0·073 | 0·324 | 0·302 | 0·133 | 0·145 | 0·098 | 0·262 | 0·086 | 0·203 | 0·296 | 0·340 | 0·071 | 0·067 | 0·123 | 0·222 | 0·035 | 0·068 | 0·040 | 0·047 |
| $Na_2O$ | 0·063 | 0·134 | 0·046 | 0·083 | 0·089 | 0·066 | 0·018 | 0·010 | 0·076 | 0·096 | 0·118 | 0·051 | 0·055 | 0·044 | 0·050 | 0·110 | 0·198 | 0·038 | 0·032 | 0·096 | 0·067 |
| $SO_3$ | 0·144 | 0·225 | 0·111 | 0·018 | 0·005 | 0·255 | 0·349 | 0·547 | 0·021 | 0·184 | 0·223 | 0·180 | 0·057 | 0·152 | 0·209 | 0·305 | 0·182 | 0·096 | 0·188 | 0·212 | 0·027 |
| $P_2O_5$ | 0·197 | 0·205 | 0·164 | 0·108 | 0·089 | 0·297 | 0·241 | 0·244 | 0·073 | 0·228 | 0·260 | 0·220 | 0·116 | 0·246 | 0·283 | 0·277 | 0·145 | 0·065 | 0·124 | 0·091 | 0·157 |
| C | 41·87 | 42·00 | 40·61 | 19·19 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 51·37 | 54·43 | 52·65 | 48·67 |
| N | 1·176 | 1·330 | 1·429 | 0·996 | 0·416 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 1·629 | 1·341 | 1·498 | 1·936 |
| C/N | 35·19 | 31·57 | 28·42 | 19·27 | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | .. | 30·71 | 40·60 | 35·14 | 25·14 |
| pH | 5·24 | 4·41 | 3·76 | 3·93 | 4·22 | 5·54 | 4·37 | 4·68 | 4·48 | 5·07 | 4·27 | 4·39 | 4·09 | 4·92 | 4·39 | 3·76 | 3·84 | 4·20 | 3·96 | 3·70 | 3·96 |

Analyses expressed as percentage over dry material.

*Site:* Bank above river, 1,050 feet O.D.

*Vegetation:* Scots pine, *Vaccinium Myrtillus; V. Vitis-Idaea, Calluna vulgaris.*

| | | | |
|---|---|---|---|
| $A_0$ | (1) | 0–1 cm. | Fresh needles (LL layer). |
| | (2) | 1–3 cm. | Layer of partially decomposed pine needles, loose and open texture, rootlets, little or no mineral matter (F layer). |
| | (3) | 3–17 cm. | Brown humified layer; plant structure not clearly visible friable and loose in texture, containing many dead roots (H layer). |
| $A_1$ | | 17–23 cm. | Black greasy layer, very moist and finely textured, compact. |

CONCLUSIONS.

From a consideration of the results, the following points may be noted.

(1) There is a tendency for both sulphate and phosphate to increase in the lower layers of the $A_0$ horizon, more especially in the second layer (F), with, however, a marked decrease in these constituents in the $A_1$ horizon.

(2) Sodium and potassium have also a tendency to increase down the profile even to the $A_1$ layer. It is interesting to note the larger amounts of potassium compared with sodium present in all the profiles except Ballochbuie, where both these constituents are relatively low.

(3) Whilst iron and aluminium both increase throughout the profiles, manganese decreases, and indeed in the $A_1$ layer is frequently present only in traces. Spruce litter (LL) is much richer in manganese than either beech leaves or pine needles. There is a decrease in the $Al_2O_3/Fe_2O_3$ (aluminium/iron ratio) from the LL to the $A_1$ layers.

(4) Comparison of the calcium and magnesium figures indicates that, whilst calcium generally decreases down the profile, magnesium tends to remain constant or increase slightly. Beech and pine litter have similar calcium contents, but these are lower than in spruce litter. Hesselman (2) also found that the calcium contents of beech and pine litter were lower than in spruce, but there was little similarity between the values of the two former.

(5) Except in the samples of spruce and beech from Pitfour, the material soluble in HCl decreases to the third layer and then increases sharply in the $A_1$. In the Pitfour samples the increase is consistent throughout the whole profile.

(6) All the samples have a high acidity more particularly in the second and third layers of the profile.

(7) It would appear that local factors are much more important in their influence on the ash constituents than are the tree species.

The author wishes to express his gratitude to Dr. I. M. Robertson for much helpful criticism and advice, and also to the Carnegie Trust for a scholarship.

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# ANNUAL EXCURSION OF THE SOCIETY OF FORESTERS TO WEASENHAM, NORFOLK, MAY 1936

BY W. H. GUILLEBAUD

THE Society held its Annual Meeting and Excursion on 26 May at Weasenham near Fakenham in Norfolk. The excursion took the form of a visit to Weasenham Woods, owned by Major The Hon. Richard Coke, who kindly showed the party round the estate. The woodlands have a total area of about 190 acres and are divided by public roads into four blocks, of which the largest and most interesting is that to the north-west, to which the excursion was mainly devoted.

The climatic conditions are probably closely similar to those in the Forestry Commission's forests at Swaffham and Thetford which lie some 10 and 20 miles respectively to the southwards. The annual rainfall averages about 26 inches, falling in dry years to well below 20 inches. Prolonged spells of cold dry winds from the north and east are often experienced in the spring and early summer, while severe night frosts occur almost every year in May and often also in June. The soil is a glacial sand overlying the chalk, and where examined under the conifers, was heavily podzolized with an iron pan from 12 to 17 inches below the surface. In one hole the pan layer (B horizon) was remarkably thick; it was encountered at 12 inches below the surface, and the bottom of the dark brown cemented layer was not reached at the depth of 26 inches. The humus covering consisted of 1–2 inches of raw humus (mor).

The vegetation varied in different parts of the wood but was often remarkably rich, indicating very active nitrification, and characterized by such plants as Herb Robert, Raspberry, Lychnis, bugle, ivy, strawberry, *Epilobium angustifolium*, &c. Bramble, bracken, and woodsorrel occurred in other parts of the wood.

The history of the wood is briefly as follows: originally somewhat openly stocked with Norway spruce and some Scots pine with an undergrowth of elder in places, the greater part of the area was laid flat by a gale which occurred in March 1895. The gale spared, however, some younger conifers, chiefly Douglas fir, *Abies nordmanniana*, and *Abies nobilis*, which had been dotted through the wood between 1880 and 1885 as ornamental specimens. Groups and single trees of Scots pine also survived in places.

The fallen trees were gradually disposed of and successive blocks netted in for the destruction of rabbits and for replanting. At this stage the dense thicket of elder which had developed presented a serious obstacle to the restocking of the area, and the elder had to be grubbed before the new plantations of Japanese larch, European larch, and Douglas fir could be established. Only the larger blank areas were restocked artificially because it was found that a profuse regeneration of a large number of species was springing up in the heather vegetation which then appears to have been dominant in the gaps

between the older surviving trees. The species appearing included oak and beech (presumably brought in by birds), Douglas fir, *Abies nobilis*, *Alba pectinata*, Norway spruce, European larch, Scots pine, and birch. In 1911 the wood was entered for the Eastern Counties Plantations Competitions of the Royal English Arboricultural Society and received a first prize. Mr. Fraser Story, who was one of the Judges at the time, reported that the area was then fully restocked, consisting partly of the remnants of the old crop remaining after the windfall, partly of thriving young plantations of Japanese larch, European larch, and Douglas fir, and partly of luxuriant natural regeneration of the species already mentioned. The seedlings were then up to three feet in height. The subsequent policy adopted by Major Coke has been of the nature of *jardinage* or selection fellings, the old trees being gradually removed either singly or in small groups, while here and there use has been made of the existing shelter to introduce groups of frost-tender conifers by planting.

The present-day result of this policy is a remarkably attractive piece of woodland. The complete stocking of the area has led to the disappearance of the heather and to the prevalence of the rich and varied vegetation already described. The younger generation of trees are almost uniformly vigorous in growth, while the large variety of species, some in pure or mixed even-aged plantations, some as natural regeneration ranging in height from small seedlings to trees 20 to 30 feet in height, and some as picturesque old trees of the original crop, give the wood a unique sense of charm. This is heightened by the introduction of Lilies of the Valley, and of flowering trees and shrubs such as *Halesia tetraptera*, Rhododendrons, and Azaleas.

The freedom with which the trees are still seeding themselves naturally is quite remarkable. Many of the species introduced by Major Coke are now beginning to regenerate; in fact it is doubtful if there is a single species within the netting enclosure which is not reproducing itself.

Since the War careful accounts have been kept on the double-entry system, with independent audit, and a good profit has been shown each year. This result is largely due to conversion of the material in the state sawmill supplying, in the main, local demands.

Some of the more interesting blocks noted included a thriving plantation of *Thuya plicata* about 25 years old; *Abies grandis* outgrowing an adjoining plantation of Japanese larch though at least 5 years younger than the latter species; some fine regeneration of Scots pine coming up under the shade of the old trees and showing the thin branching and clean form typical of what the Germans term the *Halbschattenkiefer*. The good form of these natural Scots pine was in remarkable contrast to the rough, coarsely branched, and heavily forked habit of the parent trees. In one frosty hollow, where Douglas fir had been planted, the trees were frosted year after year and many of them killed. Gradually the blanks filled up with naturally seeded pine and the surviving Douglas recovered to form a thriving mixture of the two species. A mixed plantation of Sitka spruce and ash—a surprising combination on such a site—was at least partially successful, the ash holding its own over about half the

area. Two of the most attractive patches of natural regeneration were firstly, a mixed crop of Scots pine and Douglas fir ranging in height from 6 to 20 feet, and secondly, a fine patch of Douglas fir coming up under the light shade of a group of natural Scots pine about 20 feet high. The oak, which is freely sprinkled among the young conifers, is remarkable for its straight and clean growth.

It need scarcely be said that Major Coke could not have achieved such success without the rigid exclusion of rabbits. The netting in of the area and destruction of the ground game were an essential part of the whole scheme. At the same time, considering the apparently unpromising soil, the low rainfall and the late frosts, the remarkably free natural regeneration of a wide range of species and the good growth of such relatively exacting and moisture-loving trees as *Thuya plicata*, *Abies grandis*, and Douglas fir remain somewhat of a mystery. This is an area which would repay careful investigation, especially as regards the chemical properties, reaction, &c., of the soil. Assuming that originally the soil conditions were not unlike those at Swaffham and Thetford, Weasenham Wood should provide very useful guidance as to the future management of those forests. Major Coke is certainly to be congratulated on his skilful management of this most interesting area, and the thanks of the Society are due to him for enabling them to visit it.

# THE NINTH CONGRESS OF THE INTERNATIONAL UNION OF FOREST RESEARCH ORGANIZATIONS

*Hungary 1936*

BY W. H. GUILLEBAUD

THE ninth Congress of the International Union was held in Hungary in August 1936 under the presidency of Professor Gyula Roth, head of the Forest Research Service in that country. Unlike the previous conferences, the sessions were not all held at one centre, but were spread over a number of cities including Pécs, Széged, Budapest, Debrecen, and Lillafüred. This had the advantage of breaking the otherwise somewhat severe strain of a whole week of paper-reading and conferring, but had other drawbacks, which became apparent as the Conference proceeded. Some 70 delegates (other than Hungarian) attended the Conference, Poland and Finland being especially well represented. The British Empire sent 7 delegates, including 4 from Great Britain, 1 from India, 1 from Burmah, and 1 from Australia.

The indoor work of the congress consisted partly in the presentation of papers on a wide range of subjects dealing with problems of forest research, and partly in discussing the reports of the sub-committees which had been appointed by the previous conferences.

Owing to the late delivery of many of the papers it was not possible to have all of these printed in time for the conference, and as, during part of the time two sections were meeting simultaneously, the writer is unable to give any comprehensive account of the papers presented. These will be printed in the bound volume of the proceedings which will be issued in due course from Hungary. Attention may, however, be drawn to one series of papers of special interest. These dealt with thinning investigations in relation to value increment, and represent an effort to focus attention upon the timber quality aspect of sample plot investigations. The principal contributors to this subject were Professor Wiedemann of Eberswalde, Dr. Bornebusch of Denmark, and Professor Ugrenovic of Jugoslavia. Other papers which may be mentioned include one by Dr. Eidmann of Eberswalde in which he described methods of replacing the ordinary germination tests by a chemical test, using salts of selenium or tellurium. Professor Schmidt, also of Eberswalde, read an interesting paper on the diagnosis of the racial characteristics of Scots pine by determining the phototropic reactions of the seedlings. He claimed that the method was both quick and reliable, as the analysis could be carried out on seedlings only seven days after germination.

Perhaps the most important work of the congress was concerned with the reports of the sub-committees. These had all functioned more or less actively since the Nancy Congress in 1932, and in one or two cases the tasks given were virtually completed. The sub-committee appointed to draw up a 'Standardized Scheme for making Locality Descriptions' completed its task by producing a

printed report in which three schemes are given—one for temperate and cold regions, one for Mediterranean conditions, and one for the tropics. These should be found useful, though possibly over-elaborate in some respects. The report was accepted by the congress.

Another sub-committee which completed its principal task was that on the 'Nomenclature of Humus Types'. The agreed nomenclature was approved by the International Congress of Soil Science which met at Oxford in 1935; it had previously been adopted by the congress in Nancy. This sub-committee was not dissolved, but was amalgamated with another committee, namely that dealing with the problem of degraded (podzolized) soils. This is probably a wise decision because the humus nomenclature has been drawn up primarily for forest soils, and some amendments may be necessary when dealing with humus types under non-woodland (heath and moorland) conditions. The sub-committee on 'Podzolized Soils' had little progress to report. The personnel was reconstituted, Professor Hesselman of Sweden being appointed Chairman with Dr. Nemeç of Czechoslovakia, Vice-Chairman. Dr. A. Muir of the Macaulay Institute for Soil Research, Aberdeen, is the British representative.

The sub-committee on the 'Standardization of Sample Plot Methods' produced an agreed report which has been published in German, French, and English, the English version being entitled 'Outlines for Permanent Sample Plot Investigations'. In the main, the recommendations represent a summary of the practice of the German research stations, brought up to date as far as possible to accord with the more recent development in sample plot methods. The 'Outlines' were circulated for criticism well in advance of the congress, but, as often happens in such cases, the majority of the amendments proposed did not reach the sub-committee until the congress had actually met, and it was then impossible to discuss them in detail. It was decided that the sub-committee should continue in being until the next congress and that in the interval it should consider the various criticisms and incorporate any agreed amendments. During the discussion the question was raised by several of the delegates as to how far the 'Outlines' were to be regarded as binding upon the respective research stations which might collectively approve the scheme. In reply it was made clear by Professor Fabricius of Munich, the chairman of the sub-committee, that the 'Outlines' were not intended in any way to tie the hands of the individual research stations, which remained free to retain or amend their existing procedure as they saw fit.

One of the most important of the sub-committees—that on bibliography—was unable to present any formal report. The chairman (Professor Troup) was unable to come owing to illness. Of the remaining members two, Professor Weber of Germany and Professor Jedlinski of Poland, had died since the Nancy Congress, while neither M. Perrin of France nor Professor Flury of Switzerland was able to be present in Hungary. A meeting of those interested in the question was held at Debrecen, with Professor Burger of Switzerland in the chair, at which many of the outstanding problems were

discussed. It was evident that considerable progress had been made during the past four years. Thus the scheme of indexing drawn up by Professor Flury had been generally adopted and put into operation, and the majority of the countries in Europe had issued indexed lists of their forestry literature which had appeared during the year 1934. During the discussion at Debrecen the question of the revision of the index was raised by a number of speakers, and it became apparent that some modifications were desirable; in particular the sections relating to policy and economics, and to entomology were specified as faulty. The format in which the records should be issued was mentioned by Professor Burger, who urged that these should be printed in a form in which they could be bound. He pointed out that the smaller research stations would have great difficulty in dealing with the very large number of cards which the scheme might be expected to produce, and suggested a standard size of 21 cm. × 30 cm. for the records. Those stations which had the necessary facilities could cut up the individual entries for their card index, while other stations could have them bound. Professor Abetz made three suggestions, namely (1) titles of journals should be given in full and not abbreviated; (2) the country in which the journal was published should be stated; (3) the title should specify where necessary the country or countries to which the article relates. The still more difficult question of abstracting forestry literature was raised, but in an open discussion of this sort it was impossible to do more than ventilate the problem. This and other matters will be dealt with by the reconstituted sub-committee composed of the following members: Professor R. S. Troup, Great Britain, chairman; Professor P. Flury, Switzerland, honorary member; Professor H. Burger, Switzerland; Professor K. Abetz, Germany; Professor H. Perrin, France; Professor E. Saari, Finland.

The sub-committee on 'Resin Tapping' was instructed to continue its work and to extend its activities to the collection of statistics on the industry.

A new sub-committee under the chairmanship of Professor Werner Schmidt of Eberswalde was appointed to deal with the 'Problems of Tree Seeds', and in particular to collect information as to the geographical distribution of the more important races of forest trees.

A sub-committee, with Professor Fabricius as chairman, was also appointed to make proposals regarding the 'Investigation of the Technical Properties of Timber'. Mr. W. A. Robertson is the British representative on this sub-committee.

The sub-committee on Forest Entomology was reconstituted as an international committee with Professor Trägårdh, Sweden, as chairman.

Various resolutions were put to the congress at the final session at Lillafüred. These included among others: (1) a proposal for the investigation of the influence of the forest upon the local climate; (2) the need for the pooling of work in different countries on elm disease; (3) a recommendation that all important articles in forestry periodicals should be provided with a short author's abstract in either French, German, or English and that claims

of copyright should be waived in such summaries, i.e. they could be reproduced in abstract periodicals or elsewhere, without special permission being required. These resolutions were adopted in the main and transmitted to the Standing Committee of the International Union for appropriate action. The Standing Committee consists of some eight or nine members, and meets annually in the intervals between the congresses; it plays an essential part in the work of the International Union, keeping the progress of the sub-committees constantly under review and giving effect to resolutions passed at the previous congress.

It was decided to hold the next congress in Finland in 4 or 5 years' time. Dr. Cajander was elected Honorary President, and Professor E. Lönnroth, President of the Union.

EXCURSIONS.

During the tour the congress visited most of the principal cities in Hungary, and in the course of a journey which covered about 1,500 miles by road gained a fairly good picture of the cultivation of the land and the distribution of forest. Before the Great War Hungary had very large forest properties, but in the treaty of Trianon she lost practically all her mountains which formed the rim to the great plain of Hungary, and with these over 80 per cent. of her forests. Modern Hungary consists predominantly of a vast plain, given up for the most part to the cultivation of wheat, maize, and fruit, but interspersed here and there with plantations of *Robinia pseudacacia*. There are a few minor hill ranges (the highest point in the country is not more than 3,300 feet above sea-level) covered partly with vineyards and partly with broad-leaved forest—oak, beech, hornbeam, &c. The oak forests consist for the most part of coppice converted into high forest, and those visited were of distinctly inferior quality, the stems crooked and often smothered with epicormic branches. Road communications appear to have been defective in many cases, with the result that the crops had suffered from lack of thinning. There are some fine beech forests round Lillafüred in the north-east of Hungary, which the congress visited in the latter part of the tour.

Unlike some other countries, the marketing of forest produce appears relatively a simple matter in Hungary, the timber is mostly of small size and there is almost unlimited demand for firewood. Litter also is scarce, and plantations can often be weeded without charge to the forest department in return for the grass, coppice growth, &c., yielded by the weeding.

The proportion of the total area of the country occupied by forest is about 12 per cent., and even this appears high to one who has spent a considerable number of days touring over the vast and almost treeless Great Plain. Over 95 per cent. of the forests are composed of hardwoods.

The central research station of the Forest Service at Sopron, in the west of Hungary, is under the guidance of Professor Roth, and there are a number of centres where investigations are in progress, notably an area for work on natural regeneration near Veszprém to the north of Pécs, a block of 1,000 acres of alkali soil at Püspökladány not far from Debrecen in the east of Hungary,

and a similar area of blown sand in the interriverine belt between the Danube and the Tisza. These two large blocks represent the principal types of difficult soil and are the subject of numerous experiments in afforestation. There are in addition some 40 sample plots for the study of thinning methods, and a series of exceptionally well-equipped meteorological stations comprising four double and six single stations. Where double stations occur one is set up under canopy in the forest and the other on open ground in the immediate vicinity. The instruments recorded include, in the forest stations, the usual screen thermometers, soil minimum thermometer, evaporimeter, soil thermometers at depths of 5, 10, 15, 30, 60, and 120 centimetres, rain-gauge, and a well for the measurement of the level and temperature of the ground water. In the open station there are in addition a sunshine recorder, maximum insolation thermometer, wind vane, and three different types of rain-gauge.

As already indicated the three chief lines of research actually in progress are concerned with (1) Systems of natural regeneration of broadleaved trees; (2) Afforestation of shifting sands, and (3) Afforestation of the alkali (so-called Szik) soils in the neighbourhood of Debrecen. Some account of these will now be given.

### (1) SYSTEMS OF NATURAL REGENERATION.

Professor Roth is well known as an authority on the various systems of natural regeneration, and in recent years he has developed a system of his own which he has named *Linienblenderung* or *Linienblenderschlag*. This is closely related to the *Blendersaumschlag* of Wagner in that it works in narrow strips with a very slowly progressing felling front, but differs from it in two salient features. Firstly, instead of felling on one side only of the strip, Roth proposes to fell on both sides and thus to speed up the rate of progress; and secondly, while Wagner lays down a more or less hard and fast rule that felling should proceed from north to south, the felling front accordingly running from east to west, Roth's system bases the felling direction primarily upon the topography, and felling proceeds towards the easiest line of extraction. The congress inspected several experimental areas in each of which three systems of regeneration were being practised in adjacent blocks. The systems were (*a*) Gayer's group system, (*b*) Wagner's *Blendersaumschlag*, and (*c*) Roth's *Linienblenderschlag*. The blocks were usually of considerable size, ranging from 100 to 150 acres in area, and in each case woodlands were selected in which the conditions were outstandingly good for natural regeneration. Near Veszprém the old crop consisted chiefly of 90- to 95-year-old hornbeam and beech with occasional elm, maple, and sessile oak, and in all three blocks regeneration was abundant wherever an opening was made (Plate XX, Fig. 1). Some interesting charts were prepared by Dr. Pál Magyar from which the course of the regeneration could be traced over the last 5 years. These showed surprisingly large changes in the amount and distribution of the seedling growth, frost and game damage apparently playing a considerable part in the fate of the young plants. As the experiment has only been in progress a few years, it is far too soon to

attempt to judge between the three systems of regeneration. As far as the problem of restocking the area is concerned, it is quite clear that this could be done almost equally well by any system, and the straightforward shelterwood compartment system might easily give the quickest and surest results. What remain to be shown, however, are the relative advantages of the three systems as regards extraction of produce and the damage to the young growth during the process of getting out the timber.

A similar series of plots was seen in the State Forest of Pécs. Here the old crop consisted predominantly of oak grown up from coppice shoots, with a small admixture of beech and hornbeam. The oak crop was of low quality as regards form of stem, containing a high proportion of crooked stems and evidently suffering from lack of thinning. Absence of roads previous to 1926 was stated to be the cause of the past neglect of this forest. In the southern part of the forest, where the soil conditions were favourable, regeneration was remarkably profuse. Oak regeneration was coming up everywhere even under very considerable shade, and doubts were expressed by some of the delegates as to the suitability of either of the strip systems when applied rigidly to a light demander such as oak. Here either the group or the uniform system would seem better adapted to the conditions.

(2) AFFORESTATION OF DRIFT SANDS.

The congress visited the experimental plantations near Kecskemét, a town lying to the south-east of Budapest and between the Danube and the Tisza. The rainfall here is about 20 inches per annum and the summers hot and dry. The sand, which varies considerably in composition, often overlies an earlier soil of a chernozem-like character. In one profile examined the layer of drift sand was only 2 feet in depth; this rested upon about 2 feet of black humose sand which passed fairly abruptly into a whitish sandy layer some 3 feet in thickness containing about 20 per cent. of lime; below this was a great depth of yellow sand.

An area of some 750 acres was afforested by the district forest staff in the years 1920 to 1923, principally with *Robinia pseudacacia* which covered 70 per cent. of the area; other species included poplars, birch, alder, and small quantities of Austrian pine, elm, oak, and ash. The *Robinia* throve only on the better sites, and where it failed was replaced largely by Austrian pine. In 1931 the area was handed over to the Research Branch, which began numerous experiments with a large variety of species and also stopped the clear felling—a rotation of 20 years was originally adopted, later raised to 30 years, regeneration to be from the stool shoots of the broad-leaved species—and adopted a policy of a selection type of felling in hopes of natural regeneration. Perhaps the most interesting feature of this area consists in the botanical investigations which have been in progress for upwards of 50 years. These have established a close relationship between soil quality and plant association. The associations (types) depend partly upon the depth of the water table and partly upon the composition of the sand, i.e. for a given height above the water table a different

vegetation type characterizes the coarse poor sands from that found on the more loamy and fertile sands. Seven types in all are now recognized ranging from the *Festuca vaginata* association, with four sub-types, to the *Festuca pseudovina-sulcata* association. The former occupies the upper parts of the poorer sand dunes while the latter characterizes the best loamy sands rich in humus in the upper soil horizon. As a result of close observation those vegetation types are now linked up with the appropriate tree species. Thus *Robinia*, which at first was planted more or less regardless of site, is now considered suitable for planting only on the best types, namely either the *Cynodon dactylon* or the *Festuca pseudovina-sulcata* associations. Other sites are either too dry, too low lying, or too poor for this tree. The grey poplar, *Populus canescens*, is particularly well adapted for growing on these deep dry sands. Practically the entire root system of one 20-year-old tree of this species had been dissected out, and the root exposure provided an obvious clue to the reasons for its success. One root was traced to a distance of no less than 133 feet from the tree. In the case of the grey poplar these main horizontally running roots lie deeper than in many other species and so are better able to cope with periods of drought. The vertical roots are usually small but in this particular tree were traced to a depth of 10 feet. The Austrian pine is one of the most successful species on the upper slopes of the sand hills. It copes with those conditions better than Scots pine, probably owing to its deeper-lying horizontal roots. Scots pine is preferred, however, on the better sands nearer, but not too near, to the water table. Other species employed are the white, black, and Lombardy poplars, *Juniperus communis*, *Juglans nigra*, and *Celtis australis*, and on the best soils oak, ash, elm, *Robinia*, and *Populus serotina*. One of the sub-associations of the *Festuca subovina* type, namely that characterized by the presence of *Fumana vulgaris*, differs from the other types in that it does not appear to be related to the depth of the water table. It is found on the lowest as well as on the highest sites, but always on soil very deficient in plant nutrients. This type indicates land that is useless for afforestation.

The chief practical difficulty in afforesting these drift sands lies in the extraordinarily rapid variations in site quality; good and poor sites occur in a mosaic the small scale of which greatly increases the problem of selection of species. The solution lies in the guidance afforded by the natural plant associations, and the Hungarian foresters are fortunate in the men who have studied these so effectively, notably Dr. Pál Magyar of the Research Station and Professor Reszo Soó of Debrecen University.

### (3) AFFORESTATION OF SZIK SOILS.

The Szik[1] soils of Hungary occupy extensive areas in the east of the great plain. These are alkali soils closely akin to the so-called 'Solonetz' types of southern Russia. The parent material is loess, a fine textured soil almost free from stones and often containing a high proportion of silt. These soils have developed as a result of the combination of low rainfall, high evaporation, and under-

[1] Pronounced 'seek'.

ground water rich in bases. The surface horizon is normally poor in lime and other plant foods and rests on an accumulation layer (B horizon) which may be several feet in thickness; it is usually whitish or greyish in colour and rich in sodium salts such as sodium chloride, sodium sulphate, and sometimes also sodium carbonate. The depth at which this layer occurs varies from 12 to 30 inches, and cultivation must be carefully regulated to avoid bringing it to the surface. The lower layers of the soil have a fairly high lime content. The plant associations on the Szik soils have been carefully studied and are divided by Dr. Magyar into four types: Type I, *Poa-pratensis–Cynodon dactylon*; Type II, *Festuca pseudovina, Achillea-Inula* subassociation; Type III, *Festuca pseuodovina, Artimisia-Staticc* subassociation; Type IV, *Camphorosoma ovata.* Of these Type I represents the best and Type IV the poorest conditions.

In the afforestation of these soils special attention has been paid to the root systems of the trees and shrubs. Having regard to the low rainfall, especially in summer, it appeared certain that only those plants would thrive which were able to push their roots through the very compact B (accumulation) horizon and reach the water table below. Investigations showed that on the lighter, better, types of Szik soils the roots of most of the species, e.g. Robinia, elm, poplar, pine, &c., were able to get down to the water table, but that on the more loamy soils relatively few of the species were able to push through the hard B horizon. According to Magyar the species can be arranged in the following order according to their capacity for developing deep-going vertical roots under these conditions.

1. *Tamarix* spp. and *Eleagnus angustifolia.*
2. *Quercus robur, Amorpha fruticosa, Pyrus pyraster.*
3. *Ulmus campestris, Sophora japonica, Robinia pseudacacia.*
4. Poplars, pines, maples, ash, &c.

Group 1 has the greatest and Group 4 the least capacity in this respect.

Some remarkable root dissections of oak, tamarisk, and Eleagnus on 3rd quality Szik soils at Püspökladány were shown to the delegates (Plate XX, Fig. 2). Some of these involved excavations measuring 10 feet in diameter and over 18 feet in depth. One 9-year-old plant of *Tamarix odessana* had a radial spread of 20 feet of the horizontal roots, while the vertical roots descended to 16½ feet. The water table here was at a level of 24 feet below the surface.

The experimental work at Püspökladány has been in progress since 1924 and a large number of plots have been laid down, covering a wide range of species, methods of soil cultivation, manuring, and planting. These plots have already begun to yield valuable information. The experience to date has shown conclusively the necessity for soil cultivation. The whole of the ground must be broken up by ploughing, and after planting the soil must be kept worked until the plants are established, i.e. until canopy has formed. In general success was directly in proportion to the amount of cultivation given. This work would be prohibitively expensive if it were not combined with the growing of agricultural crops. On the poorest soil (Type IV) cultivation alone is not sufficient and lime or marl must be added in large quantities as a manure.

The species allocated to the several types are as follows:

Type I. All species which tolerate the conditions of the Great Plain. This is also good agricultural soil.

Type II. *Quercus pedunculata*, *Ulmus campestris*, *Fraxinus excelsior* and *F. americana*, *Pyrus communis pyraster*. Poplar in the wetter hollows.

Type III. *Eleagnus angustifolia* and *Tamarix odessana* and *T. tetrandra*.

Type IV. Unplantable unless heavily manured with lime or marl.

It is hoped that the shrubs—*Eleagnus* and *Tamarix*—will, owing to their vigorous root development and leaf fall, so improve the soil that ultimately more profitable species can be grown.

(4) BEECH FORESTS OF THE NORTHERN HILL RANGES.

The tour ended at Lillafüred, an attractive holiday resort in the wooded hills near Miskolc. Incidentally, the hotel in which the congress was lodged had been built by and was the property of the forestry department. From here tours were made into the hills behind and also into the Matra mountains, one of the lower spurs of the Carpathians. Above Lillafüred some excellent young plantations of oak, larch, and other species were seen. The larch was notably fast growing and healthy with narrow crown and ascending branches. European larch of the lowland, Sudeten, type is probably not indigenous in these hills but in this species the Hungarians would appear to have a useful addition to their forest trees. The beech forests in the Bukk-Gebiete and in the Matra hills were quite extensive and the growth as well as the type of forest showed that the conditions here could not be far from the optimum for beech. After leaving Lillafüred, where the final session of the congress was held, the party returned to Budapest, where some of the delegates remained to take part in the second International Forestry Congress which began on the following day.

Thanks are due to Professor Roth and his Hungarian colleagues for the pains taken to ensure the success of the conference.

SUMMARY.

The ninth Congress of the Union of International Forest Research Stations was held in Hungary in August 1936. Sessions were held in Budapest, Pécs, Szeged, and other centres, at which papers were read and reports received from the sub-committees appointed at previous congresses. The principal committees dealt with the following problems: bibliography, locality descriptions, sample plot methods, humus nomenclature, treatment of podzolized soils, tree seeds, resin tapping, &c. The 1936 Congress appointed a new committee to take up the question of the technical properties of timber.

During the course of a tour lasting nearly three weeks the congress visited the chief centres of forest research in Hungary. There were three main subjects of investigation, namely, methods of natural regeneration of oak, beech, and other hardwoods, the afforestation of drift sands in the tracts between the

Fig. 1. Strip felling in the beech/hornbeam forest of Farkasgyepü near Veszprém. Roth's *Linienblenderschlag*. The abundant regeneration will be noted.

Fig. 2. Afforestation of Szik (alkali) soils at Püspökladány. Root of 10-year-old tree of *Quercus pedunculata*. Radial spread of roots 12½ feet. Vertical roots reached a depth of 19 feet.

PLATE XX

Danube and the Tisza rivers, and the afforestation of Szik (alkali) soils on the east side of the Plain of Hungary. Interesting features of the afforestation work were (1) the study of the natural vegetation and its classification into types in relation to treatment, and (2) the investigation of root development of the trees used.

# TWO SUGGESTED *NOMINA AMBIGUA*

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OWING to uncertainty as to the correct application of the names in use in current literature for the cultivated poplars, it is desirable that those which are ambiguous should be placed on an official International List of *Nomina Ambigua*. Reasons are here given for so treating *Populus canadensis* Moench and *P. balsamifera* L., which are hereby recommended for inclusion in such a list.

1. POPULUS CANADENSIS.

This name was first given by Moench in 1785 (*Bäume Weissenstein*, p. 81). It appears to have been intended for one of the *P. deltoides* × *nigra* hybrids, probably × *P. regenerata*, which originated in Europe, but not for any one of the native American species; owing to the incompleteness of the original description, however, it is uncertain to which of these hybrids Moench was referring. Henry (1) concluded, therefore, that '*Populus canadensis* Moench' 'must remain a doubtful name'. On account of this uncertainty some writers have ignored the name *Populus canadensis* Moench and have made use of *Populus canadensis* Michx. There is no question as to the application of Michaux's description which clearly refers to one of the native American Black Poplars, but as he did not publish it until 1813 his name is invalid under the Rules. Rehder in his *Manual of Cultivated Trees and Shrubs* (p. 91, 1927) has used '× *P. canadensis* Moench' as an aggregate name to include the whole group of hybrids derived from *P. deltoides* × *nigra*, treating each named clone as a 'variety', under Article 34 of the International Rules.

Dr. Houtzagers of Arnhem has pointed out, however, that it is taxonomically and genetically incorrect to adopt a varietal name for a hybrid which is in most cases nothing more than a single heterozygous individual propagated asexually. He suggests that if it is desired to group morphologically distinct clones, of the same hybrid parentage, under one aggregate name, it would be more correct to designate these clones as forms (*formae*) than as varieties (*varietates*). Dr. Houtzagers suggests that this is a case for the application of Article 31 of the International Rules, denominating each hybrid by a special 'specific' name, as has been done by Mr. Bean in the Kew Hand-list (3), but prefixing the sign × to indicate hybridity. This method of treatment would obviate the necessity for using the ambiguous name *Populus canadensis* Moench. That the original description, and therefore the application of the name, *Populus canadensis*, are ambiguous is sufficiently indicated by the fact that in published accounts of the genus it has been attributed to the following species or hybrids, e.g. to

*P. candicans* Aiton; by Dode, in *Mém. Soc. Hist. Nat. Autun.* xviii. 65, 1905; teste Henry, 1913.

*P.* '*deltoide*' Marshall (*P. deltoides* Sudworth, *P. deltoidea* Sargent, *P. monilifera* Aiton), by Michaux, *Hist. Arb. Amer.* iii. 297, t. 11, 1813, and by Koch, Dippel, et al.; teste Henry, Sargent, Sudworth, and Bean.

*P. euxylon* Dode; by Moss, *Camb. Brit. Flora*, ii. 12, t. 16, 1914.

*P. fremontii* S. Wats.; by Wesmael, Monogr. Pop. in *Bull. Féd. Soc. Hort. Belg.* 330, f. 8, 1861, in part, teste Sudworth.

×*P. marilandica* Bosc.; by Hartig. in *Vollst. Naturgeschichte der forstlichen Culturpflanzen*, 436, 1851 (where he ascribes *P. canadensis* Michx. to ×*P. marilandica* or ×*P. regenerata*); by Koehne (*Deutsch. Dendr.* 81, 1893) and Schneider (*Laubholz-Kunde*, i. 7, 1904, partly), both of whom apply it to several—especially female—hybrids of ×*P. monilifera* ×*P. nigra*.

*P. nigra* L. According to the 'Index Kewensis' the *P. canadensis* of Fougeroux de Bondaroy (in *Mem. d'Agric. Paris*, i. 94, printed 1786), is *P. nigra* L.

×*P. regenerata* Schneider?; by Henry, in *Trees of Great Britain*, vii. 1807 (footnote), 1913; and by Houtzagers (MS.), 1936.

×*P. serotina* Hartig; by Mathieu, *Flore Forestière*, 495, 1897, teste Henry.

2. POPULUS BALSAMIFERA.

The name *Populus balsamifera* Linn. is to-day in use for two different North American poplars, each of which is cultivated in Britain and on the continent of Europe, and is of commercial importance. These two species belong to two quite different groups ('Subgenera' or 'Sections') of the genus *Populus*. Much confusion has arisen from the use of the same name for both species, one in Canada and the other in the United States.

The American Black Poplar (Section *Aegeiros*) is known in the United States as *Populus balsamifera* Linn. (vide Sargent, C. S., *Silva of North America*, ix.: 167, 1896; Rehder, A., *Manual of Cultivated Trees and Shrubs*, p. 92, 1927). In Canada, however, it is known as '*Populus deltoides* Marshall'; and it was for a long time known under this name in the United States also. The American Balsam Poplar (Section *Tacamahaca*) is thoroughly well known in Canadian forestry and botanical literature as *Populus balsamifera* Linn., and was at one time so called in the United States (vide Asa Gray, *Field, Forest, and Garden Botany*, p. 400, edition of 1895, et al.). In current literature in the United States, however, it is now known as *Populus tacamahaca* Miller. In British literature it passes sometimes under one name, sometimes under the other. The different applications of the name *P. balsamifera* are traceable to differences of opinion as to what species Linnaeus really referred to; his own description, 'populus foliis subcordatis oblongis crenatis' (*Species Plantarum*, p. 1034, 1753), is admittedly ambiguous. It is not made clearer by his citation, as synonyms, of two distinct species: (1) Catesby's 'Populus nigra, folio maximo, gemmis Balsamum odoratissimum fundentibus' (*Natural History of Carolina*, &c., i. 34, t. 34, 1743), a species of the south-eastern United States which the plate shows to be one of the Black Poplars (the *Aegeiros* group), having large ovate-cordate leaves on long petioles; and (2) of Gmelin's 'Populus foliis ovatis acutis serratis' (*Flora Sibirica*, i. 152, t. 33, 1747), an Asiatic species of the

Balsam Poplar (*Tacamahaca*) group. Doubt as to the identity of the Linnaean species was experienced within a very short time after his publication of the name *P. balsamifera* in 1753. In 1768 Miller applied the same name to the Carolina Poplar, and in 1772 du Roi applied it to the American Balsam Poplar. Each view has received a considerable body of support, up to recent times.

As recently as 1919, Farwell reverted to the Millerian concept, arguing that Linnaeus really based his *P. balsamifera* on one of the American Black Poplars, probably *P. deltoides*, and Rehder (*Manual*, 1927) adopted the Linnaean name *P. balsamifera* for that species. On the other hand, Aiton, as far back as 1789, considered that Miller was in error on this point, and he reserved the epithet *balsamifera* for the American and Siberian Balsam Poplars, renaming the Carolina Poplar as *P. angulata*, referring to it Miller's *P. balsamifera* as a synonym. Henry (1913) and Bean (1934) accepted Aiton's name for the Carolina Poplar; but they treated *P. balsamifera* L. as an ambiguous name, using *P. tacamahaca* Miller in its stead. In 1914 Moss (*Cambridge British Flora*, ii. 13) recognized *P. balsamifera* L. as the name of the American Balsam Poplar, but used the name *P. tacamahacca* Miller in place of *P. candicans* Aiton, citing the latter as a synonym. Whether he was right as to *P. candicans* and *P. tacamahacca* being synonymous requires further investigation, but is a question apart from the one here under consideration. The revised (1933) edition of *Native Trees of Canada* (Department of the Interior, Canada, Bulletin 61) retains the name *P. balsamifera* for the American Balsam Poplar, but attributes it to du Roi instead of to Linnaeus, thus avoiding the confusion associated with Linnaeus's application of the name to more than one species. The 1928 edition of *Trade Names for Empire Timbers* called the Balsam Poplar *P. balsamifera* Linn., but in the 1933 edition it is called *P. tacamahaca* Mill., and *P. balsamifera* L. is given as a synonym of *P. monilifera* Ait.

As the name *Populus balsamifera* is ambiguous and has been a source of much confusion, it is recommended that it be included in the list of *nomina ambigua*.

Without attempting to anticipate the decisions of the International Committee on the Names of Economic Plants, to which the question has been referred, it seems likely that the names to be accepted will be: (1) *Populus deltoides* Marshall for *Populus canadensis*, and (2) *P. tacamahacca* Miller for *P. balsamifera* of various Authors (not of Linn.?).

## LITERATURE REFERENCES

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4. Farwell, O. A.: 'Necessary Changes in Botanical Nomenclature.' *Rhodora*, vol. xxi, 1919, p. 101.
5. Henry, Prof. A.: 'The Black Poplars.' *Trans. Roy. Scot. Arb. Soc.* xxx. 1916, pp. 14–27.

# THE FORESTRY SUB-SECTION OF THE BRITISH ASSOCIATION, BLACKPOOL, 1936

THE Rt. Hon. Lord Clinton, P.C., D.L., J.P., the appointed Chairman of the Forestry Section K, was unfortunately unable to attend owing to illness. Mr. D. W. Young, Deputy Surveyor of the New Forest, was elected in his place. Mr. T. Thomson was Secretary.

The following is a list of the authors and titles of papers:

'The New Forest', Mr. D. W. Young.

'Hill Planting', Mr. A. P. Long.

'The Afforestation of difficult Sites', Mr. J. A. B. Macdonald.

'Some Soil Problems in Forest Nurseries', Dr. A. B. Stewart.

Discussion on the Utilization of Home-grown Timber:

'The existing Outlets for home-grown Timber', Mr. F. G. O. Pearson.

'The Utilization of certain British Softwoods', Mr. John T. Smith.

'The Uses and Working Qualities of British Hardwoods', Mr. J. W. C. Agate.

'The Effects of Pruning on the Quality of Timber', Mr. G. H. Donald.

Joint with Section K (Botany).

'A Comparison of ring-porous and diffuse porous Hardwoods', Prof. J. H. Priestley and Miss L. I. Scott.

'The Beechwood Associations of southern England', Mr. Ray Bourne.

'The Position of the Beech in South Wales', Mr. H. A. Hyde.

'The Effects of dormant Buds and Roots on the Wood of *Salix alba* var. *caerulea*—the Cricket Bat Willow', Mr. Henry P. Hutchinson.

'Timber and its Substitutes', Mr. E. H. B. Boulton.

'Mycorrhiza in Rhododendrons', Mr. G. H. Gordon.

'Working Plans for the private Estate', Mr. B. Pollard-Urquhart.

# SOCIETY'S AND OTHER NEWS

## NOMINATIONS FOR OFFICE-BEARERS

The Editor of the Journal, Business Editor, Secretary and Treasurer, and Auditor have been nominated for re-election at the next Annual General Meeting, and the following additional nominations have been received: *President*, W. L. Taylor, Assistant Commissioner, Forestry Commission (England and Wales); *Vice-President*, W. A. Robertson, Director of Forest Products Research; and *Councillor*, Dr. R. C. Fisher, Forest Products Research Laboratory. As there is no competition for any office a ballot will not be required. In addition to the above, two Councillors will have to be nominated and elected at the Annual General Meeting as there are three vacancies for Councillors.

## CORRECTION

In *Forestry*, x. (1), 1936, p. 2, lines 42 and 43, for 78° F. read 78° C., and for 65° F. read 65° C.

# REVIEWS

## Recent Publications on Soil Science.

Reviews by A. Muir

(1) *Nosusināšanas ietekme priedes un egles pieaugumā purvaugsnās Latvijā* ('The influence of drainage on the growth of pine and spruce on moor soils in Latvia'). By R. Markus. Latvijas Mezu Petisanas Stacijas Raksti, 1936.

(2) '*Trends in the Nitrogen, Phosphorus, Potassium and Calcium Content of the Leaves of some Forest Trees during the Growing Season.*' By H. L. Mitchell. *Black Rock Forest Papers*, 1936, vol. i, No. 6 (July).

(3) '*A Study of the Soils in the Hill Areas of the Kulu Forest Division, Punjab. Part I. An Investigation, of Soil-profiles under Deodar, Spruce, Blue Pine, and Chir.*' By E. McKenzie Taylor, I. D. Mahendru, M. L. Mehta, and R. C. Hoon. *Indian Forest Records* (n.s.), *Silviculture*, vol. i, No. 2, 1936.

(4) *The Study of the Soil in the Field.* By G. R. Clarke. Oxford Univ. Press, 1936. Price 5*s*.

(1) By moor soils the author of this detailed report understands a soil having as its surface-layer not less than 20 cm. of peat. As in Britain the Baltic countries have a superabundance of this type of soil, Latvia in particular having something like 600,000 hectares under the control of the Forest Department. The main types considered are the fen (*Niederungsmoor*) and transition moor (*Uebergangsmoor*), the raised moss (*Hochmoor*) being found to be difficult if not impossible to drain. The report gives the site characteristics of the numerous plots investigated and follows these with details of the tree growth, stratigraphical character of the peat, together with certain chemical determinations.

Three main types, (1) Carex, (2) Forest, (3) *Sphagnum*, are recognized, and it is shown that the response of the trees to the drainage of these peats is in that order, being greatest on (1) and least on (3). The mineral and nitrogen contents of the soils decrease on the average in the same way. The increase in tree height is usually attained during the first 10 years and the maximum attained during the second 10 years after drainage. With increase in age of the trees and the drain intervals the effects of the drainage is delayed for about 30 years (rarely 40). Spruce reacts to drainage much more readily than pine, and the latter may therefore be displaced.

(2) Agricultural workers have long used the chemical analysis of plants to evaluate the quality of soils for plant growth, and it would appear from this paper that a similar method may be applied to site evaluation for forestry purposes. It is shown that the absolute amounts of the major mineral constituents and nitrogen increase throughout the growing season and reach a maximum just before yellowing. After yellowing the absolute amounts of N, P, and K decrease, but no loss of Ca was observed. There is no movement of N, P, and K back from the leaves to the bole while the leaves are active and growing. It is evident that site variations will be reflected in the contents of the various nutrients, but the sampling technique presents difficulties and obviously requires special study in any given case.

(3) Lack of satisfactory profile descriptions accompanied by chemical analyses that might elucidate the development of the soils has been very marked in Indian pedological literature. The present report marks a distinct advance, and it is to be hoped that the work will be extended. The soils described occur in a mountainous area under conifers, and topography obviously plays a very great part in their formation, with the result that their relationship to the major world groups is occasionally difficult to establish. According to the authors the majority fall into the group of podzolized soils, but very few are typical. A very marked feature of most of the soils is the remarkably high exchangeable base content of the surface organic layer, which is almost completely saturated. It is evident that, although loss of clay and sesquioxides can be shown, these soils cannot be true podzols since high base unsaturation is a prerequisite of the podzol type. The lack of any definite relationship between the exchange capacity and the clay and organic matter content is noticeable, and the differences between calculated and observed values is sometimes considerable.

There appears to be a definite relationship between the growth of the different trees (chir, deodar, blue pine, spruce) and the soil type. The deodar and blue pine thrive best on well-developed podzols, whereas spruce does well on a more extensive range of types.

(4) The accurate description of soils in their natural surroundings is a very necessary part of all soil studies and until now no book in English dealt with this aspect of the science. Mr. Clarke has made an excellent attempt to fill this gap in our literature, and his little book deserves to be widely read. He begins with an examination of the soil site and its various components and then passes on to an account of the various morphological features of the soil which require description. The section on humus and soil structure has already appeared in this journal. The various methods for recording soil descriptions are fully discussed and the reader will have no difficulty in choosing one to satisfy his requirements. A brief account of the methods of regional survey completes the book.

'*Zur Frage über die Methodik der Auswahl der Modellstämme und der Proben aus ihnen zur Bewertung der physikalisch-mechanischen Eigenschaften des Holzes von Beständen.*' By A. Kondratiew. *Zbl. ges. Forstw.* 1936, lxii (1), 1-15.

Review by E. D. van Rest and S. H. Clarke

THE variability of trees and timber is a by-word among those who work with them, and the task of obtaining a figure to express the condition or quality of material from a particular locality is beset by many difficulties. Not the least of these is the problem of size of sample. Given a forest, how many trees must be measured? How many must be cut down? How many samples must be taken from each tree to ensure a satisfactory measure of the specific gravity, ring width, mechanical strength? From what parts of the tree should these be taken? Such questions can only be answered after a preliminary study of the variation encountered, and the author began by examining material from two distinct classes of pine forests. From each forest he chose thirty-three trees as representative of selected half-hectare zones. After studying specimens from these trees he developed a procedure which, he believes, can be extended to other types of forest.

In approaching a new forest he advises that a test area (or, better still, two areas) be selected. These should fairly represent the whole area and should contain not less than a hundred trees. Full silvicultural and ecological records should be made, and every tree must be callipered, and the height and crown proportion must be determined in a sufficient number of cases to enable their variability and relation to diameter to be

calculated with a sufficient degree of accuracy. In order to obtain average figures with an accuracy of ±5 per cent., in most cases the measurement of fifteen trees will suffice.

In order to determine specific gravity, compressive strength, and bending strength with an accuracy of 5 per cent. and other strength values with an accuracy of 10 per cent. it is stated that six trees will usually suffice. The author recommends that test-pieces be taken from two heights in the stem, namely breast height and at half the total height, and at each of these heights samples should be taken from four positions between pith and bark. Further examples of a spruce and a larch forest are briefly mentioned to show that the method may be extended with little modification.

Thanks are due to the author for a contribution in an important field of research. The relevant literature records many timber tests in which the adequacy of the material employed has been open to question, and it is only comparatively recently that methods have come into general use for deciding such problems. The usual aim has been to obtain a single figure (the mean) to represent a set of observations in spite of an 'unfortunate' inherent variation in the material, and it has been recognized that much depends on the number of test-pieces examined. The variation itself is now more commonly regarded as an essential characteristic to be recorded in the complete description, and even while reading Dr. Kondratiew's paper it must constantly be borne in mind that comparisons are to be made between groups of observations, and not simply between single values such as averages.

Dr. Kondratiew has first measured the existing variation and then used it to determine how many test-pieces are necessary to obtain a mean with a predetermined accuracy. His exposition carried, however, an implication which should be further explored, for the simple statement that results obtained in such and such a way will have an accuracy of 5 per cent. is incomplete. It is not possible to state definite limits between which the means of successive samples will lie, but we can say how likely it is that they will lie between any chosen limits, so that a complete specification of accuracy will include a statement both of the limits and the probability that the means of successive samples will lie between them (see *Trop. Woods*, No. 40, p. 27). By adjusting the number of test-pieces to make the average deviation of their mean 5 per cent. of the observed mean, Dr. Kondratiew has only ensured a probability of 80 per cent. (i.e. a 4:1 chance that the means of repeated experiments will lie within the 5 per cent. limits). It is more usual in this type of research to require a probability of at least 95 per cent. (i.e. 19:1), and it follows that in order to keep the same 5 per cent. limits the number of test-pieces must be increased about fourfold.

*The Effect of Rate of Growth upon the Specific Gravity and Strength of Douglas Fir.* By J. B. Alexander, B.Sc. Forest Products Laboratories of Canada (Forest Service Circular 44, Department of the Interior, Canada).

Reviewed by C. B. Pettifor

An easy, reasonably reliable means of estimating the strength of a piece of timber, without destroying it, is very desirable for commercial purposes. The best index of quality is probably the specific gravity, but unfortunately its determination, bound up as it is with that of the moisture content of the timber, is hardly practicable commercially. The proportion of summerwood in the annual ring and the growth rate (or ring width) are two visually determinable characteristics which have also been used to assess strength. The first of these, however, is not easy to measure, even under laboratory conditions, as the line of demarcation between the springwood and the summerwood is often ill defined. Only rate of growth is left, therefore, as a possible visual index of quality

practicable in commerce; and the pamphlet under review gives the results of tests made in the Forest Products Laboratories of Canada to determine how far growth rate served as an index of strength for Douglas fir. The material was tested in the unseasoned state, test-pieces and testing procedure conforming to standard practice. The range of ring widths was very wide, from 3 to 83 rings per inch, the wide-ringed material coming from near the pith, while the sapwood provided all the narrow-ringed material. The properties investigated were specific gravity, modulus of rupture in static bending, and compressive strength along the grain. Graphs are given showing the relations of each of these properties in turn with the growth rate as measured by the rings per inch. These graphs are all similar in type and show a marked increase in the property concerned, as the number of rings increases from 3 to about 12 per inch. With still narrower rings, the change in these properties is practically negligible, the values fluctuating about some common mean as the number of rings per inch increases.

The export grading rules for British Columbia specify, for Douglas fir, a growth rate of 6–20 rings per inch for the higher Structural grades, but it is shown from the results obtained in this investigation that the upper limit could safely be omitted.

*The Strength of Douglas Fir Telephone Poles.* By J. B. Alexander, B.Sc. (Forest Service Circular 45, Department of the Interior, Canada). 1936, 19 pp., 2 plates, 4 diagrams, 6 tables.

Review by J. Latham

THE principal species hitherto used for transmission poles in Canada has been Western red cedar. The demand is now such, however, that other species have come up for consideration, among them Douglas fir, which is available in considerable quantities and which, by virtue of being higher in bending strength than the cedar, is particularly suitable for heavy-duty poles. The very high durability of Western red cedar has enabled poles of this species to be used without preservative treatment. Douglas fir, though naturally much less durable, may fortunately be satisfactorily impregnated with creosote and when so treated gives long service. The series of tests described in this report were therefore undertaken to provide the necessary strength data to enable Douglas fir to be employed. In all 81 poles were tested, 28 of which were untreated, the remainder being creosoted by the boiling under vacuum empty cell-pressure process. It was found that under the pressure treatment employed the preservative completely penetrated the sapwood. Prior to test the poles were placed upright in a tank of water immersed to the ground line and left to soak for 4 months in order to bring them to the condition of moisture content of poles in the ground at the critical season. The average bending strength of the treated poles proved to be not less than their average strength when green. The results establish the strength of this species in pole sizes and enable comparison to be made with other species for purposes of substitution. They also provide the necessary data for design.

*The Sawmill Industry in Scandinavia and Finland and the Exports of Sawn Softwoods from these Countries.* By Eino Saari. 42nd Report of the London and Cambridge Economic Service. April 1936.

Review by J. T. Smith

IN previous publications elsewhere the author dealt with investigations into the cost of raw materials in the Finnish sawmill industry and other forest products research work in the same country, and has now contrived in the space of some fifty pages aided

by maps and tables to produce a clear picture of the sawmill capacity and the forest resources behind the industry in Norway, Sweden, and Finland. He traces the growth of production and the changes in the character of the exports (especially from 1913 to 1935). He relates these to the world demand and discusses the exports of sawn softwoods from Russia, Poland, Canada, and the United States with particular reference to the market for sawn wood in Great Britain. He has obviously taken considerable trouble to obtain comparative data, and his detailed examination of the structure of the exports from each country has a wealth of statistical detail which we have not previously seen in any publication on this subject. His references to existing literature are particularly valuable, covering as they do important researches in several countries.

Of special interest to foresters will be his statistics of the forest resources of the northern countries including stocks of growing timber (distinguishing between timber of sawmill size, that is about 8 inches at breast height, and smaller timber), the annual growth, and the *per capita* of population relationship. He brings out that in Finland there is more pine of sawmill size than in Sweden, and in Sweden there is more spruce of sawmill size than in Finland. He rightly points out that the growth is not identical with sustained yield, but in the absence of better information he deduces that the annual cut in each of these countries, and also in Norway, is below the annual growth. His conclusions are based on the present forest resources and on the present condition of the forests. He claims that the yield of the forests can be increased considerably by better management without extending their area, but only over many years.

Those interested in the commercial side of the industry will envy the ease with which the author is able from the available statistics to discuss the relative merits of pine and spruce as raw materials for the sawmill industry, the economic importance of large logs (even where the quality of large and small logs is identical), and the relation of the value of the logs to the selling price of the sawn wood, in both cases, *at the mill*. There is a useful field for research in this direction in this country, where the high cost of transport from the standing tree into the mill and also out of the mill to the markets is the key to the whole problem here.

The diagrams accompanying the memorandum make the statistics particularly vivid.

*A Preliminary Survey of the Forest Types of India and Burma.* By H. G. Champion. Indian Forest Records (New Series), *Silviculture*. Vol. i, No. 1. Government of India Press, New Delhi. 1936. 286 pp., 40 illustrations, 2 maps. *17s. 6d.*

Review by R. Bourne

THIS compilation has been produced in an attempt to meet the need of a standard classification for the important forest types of India and Burma in connexion with silvicultural work, particularly in its application to forest management under working plans. While many have contributed to the work, especially the provincial silviculturists, the author is primarily responsible for the classification, which is based largely on his own observations and field notes made in all parts of India during the past 20 years. 'The classification is published with the definite object of calling forth constructive criticisms which will enable some one to revise and complete the much needed survey as soon as possible; if it succeeds in eliciting this criticism it will have served its purpose.'

In the first four sections of the Record the factors determining forest types and the problems of their classification are reviewed briefly. A classification of forest types is then tentatively put forward 'based on four temperature zones, tropical, sub-tropical,

temperate and alpine, each subdivided on available moisture as reflected by the relative importance of evergreen, deciduous and thorny trees'. Fifteen main climatic formations are thus distinguished according to their physiognomy and largely independent of their floristics—Tropical forests (6), Montane subtropical forests (3), Montane temperate forests (3), and Alpine forests or scrub (3).

In the tropical forests the six formations distinguished are the Wet evergreen, Semi-evergreen, Moist deciduous, Dry deciduous, Thorn and Dry evergreen forests. With the exception of the last, these formations are 'subdivided into southern and northern forms, the difference becoming less obvious the drier the type. The difference is to some extent in form, but largely floristic.' The floristic differences in the southern forms, as between the Peninsula and Burma, are subsequently allowed for by the recognition of western and eastern associations. Striking differences occur in the northern forms between the west and the east, as well as in the tropical formations. Indeed, it would appear that a more natural classification would have been obtained by recognizing four main regions—the north-west, north-east, south-west, and south-east.

In the division of the formations into associations, &c., 33 climatic climax associations are provisionally recognized in the Moist tropical forests, 10 in the Montane subtropical forests, 8 in the Temperate forests, and 4 in the Alpine forests. In some instances data is available for the subdivision of these associations into types. In addition to the 55 climatic climax associations, 24 subsidiary edaphic associations, 16 primary seral types, and 19 secondary seral types are distinguished as having a distinct physiognomy.

The principle according to which climatic and edaphic associations have been distinguished may be quoted. 'In considering the relation of vegetation to climate in the wide sense, one would like to be able to begin with the best developed growth on mature soils typical of the climate, but the difficulties this procedure presents are at present too great and it seems preferable to compare forest found on average soils where the depth is medium and the soil is well drained without being unduly favourably situated topographically. In view of these considerations, such forest will be considered as "climatic climax" and the types found on much lighter or heavier or otherwise different soils as edaphic variants on it.'

The application of this principle has led in very many cases to the grouping together of types which have very little or no relation to each other and to the separation of types which are closely related. For instance, seral and edaphic types of one climatic zone, which are referred to in footnotes as probably being of seral or edaphic status, are often grouped with the so-called climatic climax types of another zone, primarily on account of their similarity in form and possibly also in floristics. Examples of such grouping occur almost throughout the classification. Types are only classified as seral or edaphic if they are distinct from all other types as to form or floristics.

In fact, an analysis of the data suggests that, apart from the zones of high rainfall and atmospheric humidity, a classification based on the polyclimax rather than the mono-climax theory would more closely fit the facts. These, it must be recognized, are presented for the first time for the whole of India and Burma in the form of type descriptions, some in great detail. The descriptions are accompanied by excellent illustrations and constitute an extensive foundation for future work.

Thus, although the classification is open to serious criticism, the descriptions and the author's notes on the probable ecological status of the several types and sub-types are a very valuable record. If Working Plans Officers will study these notes, in the light of the data they have collected, they should generally be in no danger of confusing a seral with a climax type, though classified in the Record as the latter. For example, a Working

Plans Officer in S. Malabar, who has systematically studied the vegetation, is not going to recognize any climatic climax such as 2aC2, West Coast Tropical semi-evergreen forest (pp. 56–7); he will recognize the forest described as a secondary seral stage of the West Coast Tropical Evergreen (*Cullenia–Palaquium* Association), which is what Champion warns him may be the case. Nor will he recognize any climatic climax such as 3aC1 (pp. 72–3) or specially distinguish as edaphic types E2 (p. 90) or E10 (p. 96). All the forests which occur in the coastal plain are secondary seral communities produced by fire or clearing. As a result of exposure secondary changes have been brought about in the soil, partly through the intensification of laterization and partly by soil erosion. A whole series of seral communities exist, in general covered by the descriptions referred to, but varying with the history of each site and the change in the soil. It is highly improbable that the true climax types could ever return except as fringing forest, but there is evidence to suggest that secondary sub-climax forms of evergreen and semi-evergreen forest could be supported in time by the changed soils. It is in such a case that the Working Plans Officer must be careful not to be misled by the classification.

# NOTICES

*Zeitschrift für Weltforstwirtschaft.* ('Review of World's Forestry'). Edited by F. Heske and Ward Shephard, vol. ii, 1934–5. J. Neumann, Neudamm.

THIS German journal continues its ambitious effort to bring the wisdom in forestry matters of central Europe, and particularly Germany, to less fortunate countries—particularly the United States of America. A number of the articles in this volume deal with North America and other foreign countries, but they generally finish with a statement of the moral from the German point of view. Nevertheless several of the articles are of general interest. Professor K. Rubner contributes an article on 'Natural forest Types in Europe'. The subject is a large one to be dealt with in the compass of 76 pages, but a general bird's eye view is given, illustrated by many excellent photographs. In an article on 'Important Trees and Shrubs of the Far East' Forstmeister Buhrmeister-Eymern describes various species considered suitable for introduction into Germany, amongst these are various *Abies*, *A. hollophylla*, *A. sibirica*, *A. nephrolepis*, *A. gracilis*, *A. sachalinensis*, attractive because of their frost hardiness. There is an interesting article by Dr. Buchholz on 'The Forest Area and Growing-stock of the Soviet Union', in which is presented a considerable amount of statistical data from Russian sources. The great need is the development of transport facilities, so that the abundant resources of one part of this great territory may be available to another part where there is a shortage of timber. It is stated that in the northern forests, swamp is steadily invading forest, and tundra is spreading southwards. There is a well-illustrated article by Dr. Ebner on 'A Critical Survey of Forest Utilization in America in Relation to Modern Problems'.

*The Identification of Trees and Shrubs.* By F. K. Makins. Dent, London, 1936. Price 15*s*.

THE identification of the great number of trees and shrubs, native and introduced, which are to be found in this country, is a matter of difficulty even for the expert. The author is to be congratulated in making this attempt to provide a means to do this. The method is to provide a line drawing of the leaves, and generally also the flower and fruit, of each species, followed by a simple key. How far the attempt is successful can only be determined by the use of the book over a period. A study of the plates and key suggests that the average person will have some difficulty in identification by the means provided. Nevertheless, the book is a definite acquisition to our horticultural literature at a time when there is an increasing number of people interested in trees and shrubs.

*Forest Insects.* By R. W. Doane, E. C. van Dyke, W. J. Chamberlin, and H. E. Burke. McGran-Hill Publishing Co. Ltd. London. 1936. Price 25*s*.

THIS book deals with the forest insect pests of North America. This is the first text-book of its kind, and is to be welcomed. It covers the usual field; the first chapters deal with methods of control, then follow chapters dealing with beetles, moths and butterflies, sawflies, aphids, termites, &c. The general principles discussed, for

example the relation between climate, food-supply, silvicultural practices, &c. on insect numbers and methods of control, do not break new ground, but the sections are concise if not extensive, and the book is well balanced. Some of the more important forest insect pests in the United States are: The western pine beetle, *Dendroctonus brevicomis*; *D. monticolae*, very destructive to Lodge pole pine; the spruce budworm, *Cacoecia fumiferana*, which has been so destructive to spruce and silver firs, particularly in Eastern Canada; the tent caterpillars, *Malacosoma* spp., frequently destructive to broad-leaved trees; and the European larch sawfly, *Lygaeonematus erichsonii*, which has defoliated extensive areas of larch in Canada and the northern part of the United States. One is a little alarmed to see listed the large number of insect pests of the American conifers we grow: Douglas fir, Sitka spruce, *P. contorta*, &c. Fortunately most of them are not serious pests, but it is highly desirable that we should protect ourselves against their introduction, by continuing to prohibit the importation of forest trees.

*British Animal Tracks.* By J. S. R. Chard. Pearson, London, 1936. Price 3*s.* 6*d.*

THIS is an interesting and well-illustrated book. It deals with the tracks, and to some extent the habits, of British wild mammals. Considering the large number of text figures illustrating the tracks, the price is modest, and we recommend all foresters and others interested in the countryside to purchase this book.

*Sixteenth Annual Report of the Forestry Commissioners.* H.M. Stationery Office, Adastral House, Kingsway, W.C. 2. 1936. Price 1*s.*

THE report describes the activities of the Forestry Commission in the usual form. During the year, 21,492 acres were planted, 31 acres naturally regenerated, 2,938 acres thinned, and 580 acres felled. The annual grant-in-aid will be increased to £500,000 for the next five years, and there is to be new work in the Special Areas, where it is hoped to acquire 200,000 acres, and form 1,000 forest workers' holdings. Additional funds will be available for this work. Three forests will commemorate the Jubilee of His late Majesty King George V. An area of 6,000 acres in Suffolk has been named The King's Forest, Vaughan Forest in Wales has been renamed Coed-y-Brenin (The King's Forest), and in Scotland the Forest of Glenmore will be known in future as The Queen's Forest.

'*Studies on the Pine Shoot Moth* (*Evetria buoliana* Schiff.).' *Forestry Commission Bulletin*, No. 16. H.M. Stationery Office, 1936. Price 1*s.*

THIS bulletin consists of two sections, part 1 on 'The biology and forest relations of the Pine Shoot Moth', by the late C. C. Brooks, and part 2 on 'The status of the pest in East Anglia and experiments on control', by J. M. B. Brown. This insect is one of the most destructive pests of pines in the south and east of England, not as a killer of trees, but as a cause of deformation of stems. Scots pine suffers most, Corsican pine is relatively resistant, but *P. contorta* suffers severely. The Forestry Commission's Scots pine plantations in East Anglia have suffered in particular, but it is encouraging that there is evidence of some abatement in the incidence of attack. The larger trees are usually attacked and deformed, and it is hoped by removing these early so that smaller and straighter trees can grow into the canopy that the permanent damage to the plantations will be minimized. There is also hope that one or other of the numerous hymenopterous parasites of the Pine Shoot Moth will prove increasingly effective in control.

*'The Cultivation of the Cricket Bat Willow.' Forestry Commission Bulletin* No. 17. H.M. Stationery Office. 1936. Price 2*s.*

DR. J. BURTT DAVY and Mr. W. R. Day have been principally responsible for the preparation of this interesting and instructive bulletin. It deals comprehensively with the selection of site for growing this species, propagation, planting, tending, pests and diseases, character and uses of willow timber, and the systematy of Cricket Bat Willow and its allies. The selection of site is of first importance in producing good bat timber; a warm sunny climate is necessary, and a well-drained, deep, loam preferably near running water provides the optimum soil conditions. The best material for planting is still in doubt; both unrooted sets and rooted plants are used, but in each instance there should be a stem clear of branches and defects, 8 feet from the soil level. Mound planting is now being used, and the best planting distance is 30 to 40 feet. The 8 feet stem must be kept clear of branches by rubbing off the buds when soft. Watermark disease is the greatest danger. It is seen, therefore, that this is not a tree which can be grown well easily, but the produce is valuable, the price paid for good trees 11 to 13 inches quarter-girth being £4 to £10.

*Report on the Demand for Timber in Wood-turning in Great Britain. Forestry Commission Utilisation Series,* No. 3. H.M. Stationery Office. 1936. Price 1*s.* 3*d.*

WOOD-TURNING is both an old and an interesting industry, because of the great variety of articles produced. It is also an important one employing 60,000 persons. Unfortunately it is declining, because current fashion favours simplicity and straight lines in design and the machine-made, mass produced, material is displacing the more individual hand-turned articles. A considerable amount of home produced timber is used, and it appears that this could be increased by better service in supplying sizes of timber required and seasoned ready for use. The Report, which is based on inquiries carried out by Mr. David Maitland, is a publication of more than usual interest which will repay careful study.

*Report of the National Forest Park Committee.* H.M. Stationery Office. 1935. Price 6*d.*

THIS publication gives the Committee's recommendations for the formation of a forest park on the surplus and unplantable land in the Forestry Commission's Forests at Ardgarten, Glenfinart, Benmore, and Glenbranter in the county of Argyll. These have been given effect to, and we hope that this Argyll Forest Park will be the first of a series for the enjoyment of that increasing section of the public which wishes to explore and enjoy the more remote and beautiful parts of our country.

*Afforestation in the Lake District.* Report by the Joint Informal Committee of the Forestry Commission and the Council for the Preservation of Rural England. H.M. Stationery Office. 1936. Price 3*d.*

THIS publication records the recommendations of the Committee on questions regarding further afforestation in the Lake District. It is recommended that a central block extending to about 300 square miles should be reserved from afforestation,

and on certain adjoining areas special regard should be paid to amenity in planning planting operations.

*Report of the Forest Products Research Board for the year 1935.* H.M. Stationery Office. Price 2*s*.

THE Report describes and illustrates the work of the Forest Products Research Laboratory at Princes Risborough in all its branches. Its work is expanding steadily, and increasing demands are being made on it by industry. The laboratory has now been equipped for the testing of boxes, and this should lead to improvements in design and specification in this important industry. The work on home-grown timbers has been continued. It was found that Corsican pine poles were a satisfactory substitute for imported redwood poles so far as strength was concerned, but owing to the higher proportion of sapwood in the former complete impregnation of it to meet the Post Office specification could only be secured at higher cost. Sitka and Norway spruce poles were inferior in strength. It was found that impregnation of the latter was greater when the fungus *Stereum sanguinolentum* was present. Preliminary inquiries were begun into the suitability of home-grown Scots pine for street paving, and of home-grown spruce for pulping. The latter may be of great importance when large quantities are available from thinnings.

*The Principal Rots of English Oak.* By K. St. G. CARTWRIGHT and W. P. K. FINDLAY. H.M. Stationery Office. 1936. Price 2*s*.

IN format this publication is the most attractive that has come from the Forest Products Research Laboratory, and it and the Stationery Office are to be congratulated. In substance also the publication is noteworthy. The rots of oak, in standing trees, felled, and in use, are described simply and concisely, and suitably illustrated. In standing trees, *Polyporus sulphureus* is the most important cause of decay; on the other hand *Fistulina hepatica* enhances the value of the timber in the early stage of attack, producing the valuable 'brown oak', *Daedalea quercina* and *Stereum hirsatum* are important causes of decay in felled oak, while the Dry Rot fungus and *Phellinus cryptarum* may be serious in buildings.

*Forest Products Research Records.* H.M. Stationery Office. 1936. Price 6*d*. each. No. 11. 'The Properties of Home-Grown Oak'; No. 12. 'Seraya, Meranti and Lauan.'

THE first deals in a lucid and simple manner with the characteristics of oak timber, and its insect pests and fungus diseases.

The second record deals with Bornean, Malayan, and Philippine timbers produced by members of the important tropical family *Dipterocarpaceae*.

*Forest Bibliography to 31st December, 1933*, Part I. Department of Forestry, University of Oxford. 1936.

THE present section gives the titles of papers dealing with general forestry, general silviculture, and seed and seedlings in the library of the Oxford School of Forestry. This bibliography is considered to be a fairly complete list of papers, bulletins, and other matter published in English, and a considerable amount of literature published in

French and German. It will be increasingly valuable to investigators and others who wish to acquaint themselves with the literature of the subjects in which they are interested.

*Australian Forestry*, vol. i, No. 1, June 1936.

WE extend a hearty welcome to this new journal, the publication of the newly formed Institute of Foresters of Australia. We hope that it will have a long and successful history. Mr. S. L. Kessell is both president of the Institute and the senior editor. The journal contains a number of interesting articles on different aspects of Australian forestry, three of which may be mentioned, 'Plant Nutriants and Pine Growth', by S. L. Kessell and T. N. Stoate, 'Root Development in *Pinus pinaster* and the Seasonal Variation of its Mycorrhizae', by Nancy T. Burbidge, and 'Soil Science as a Factor in Modern Forestry Practice', by James O'Donnell. These indicate the interest in soil conditions in Australia.

*The Empire Forestry Journal*, vol. xv, no. 1. 1936.

WE offer our congratulations to the Empire Forestry Association on the improvements made in the format of its journal. The page size has been increased to that of this journal, and improved type used. We feel certain that these changes will increase the popularity of this important forestry periodical.